OUTLINES

OF

HUMAN PHYSIOLOGY.

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PREFACE

TO

THE THIRD EDITION.

In preparing this edition of the Outlines of Physiology, I have endeavoured to introduce all the most important facts which have been lately ascertained in this department of science; and to assign their proper value to those which tend the most directly to the establishment of general principles.

In the present imperfect but rapidly advancing condition of the science, it is hardly possible to avoid occasional errors of omission in the account given of the facts that have been ascertained; and it is likewise impossible, and, if possible, I doubt if it would be desirable, to exclude all hypotheses from the inferences which are deduced from them. If hypotheses are introduced sparingly, and the grounds on which they rest fairly stated, they are admitted to be part of the process by which the knowledge of the truth is attained, even in the most strictly inductive sciences; and those who profess to reject and despise them, are not those whose opinions are the most exempt from their influence.

I have ventured to introduce a separate preliminary Section in this Edition, in which I have attempted to state the most general laws and conditions of vital action;

and to define, with as much precision as the present state of our knowledge permits, the nature of those vital properties or powers, to which we must refer as the agents immediately concerned in producing the phenomena of life.

In making the statements in that section, I am perfectly aware of the reprehension, and even ridicule, with which these vital powers or forces have been treated by some physiologists, who regard all such powers as visionary or hypothetical; but using these terms only as general expressions for the unknown causes of phenomena which have been studied, classified, and generalized, and which are peculiar to the living state, I confidently maintain, that the reference to such ultimate facts or general principles in Physiology is perfectly in accordance with the rules of true philosophy. They may, indeed, have been inaccurately conceived, and future observers may be able to define their province more accurately, and to reduce their number; but it were easy to shew, that the progress of this, as of other sciences, has been more retarded by the *premature* generalization, which attempts to include its peculiar phenomena under the general laws of nature, than by the *imperfect* generalization which may have inaccurately defined, or unnecessarily multiplied, the first principles of the science itself.

We all admit that the attempts formerly made to include all physiological facts under the general laws, either of Chemistry or Mechanics, involved hypotheses which were not only erroneous but injurious; and the same judgment may be passed, as I believe, on the attempt, in

the present state of the science, to refer all the phenomena of vital motion to muscular contraction, all those of muscular contraction to nervous influence, all those of nervous influence to galvanism, or all those of the capillary circulation and secretions to the impulse given by the heart and arteries. But if these phenomena are peculiar to the living state, and inconsistent with the general laws of Mechanics and Chemistry,—to study them in different classes of living beings, and deduce from that study the general laws, peculiar to living beings, according to which they take place, *i. e.* the *vital* powers or properties on which they depend,—is to follow the same method which has led to so great results in the other physical sciences.

It seems to me to be of peculiar importance, particularly in reference to Pathology, to establish the existence and illustrate the importance, of a principle affecting the motion and distribution of the fluids of living animals, peculiar to their living state, and independent of the impulse or pressure of their living solids. This principle of Vital Attraction and Repulsion, is more fully recognised by the physiologists of Germany than by those either of France or of this country; and as I confidently expect that, notwithstanding the opposition it has lately met with, it will gradually make its way in Physiology, I hope I may be excused for observing, that almost all the facts stated in this volume in illustration of it, were noticed with that intention in my lectures, and in a paper read to the Royal Society here, before the publication of the important works either of Muller or Burdach.

I need hardly say, that all the important additions recently made to the Physiology of the Nervous System, tend only to give more extent and precision to the general principle which was first clearly established by Sir Charles Bell, that in reference to the different mental acts with which they are connected, and on their connection with which their use depends, the different portions of the Nervous System, however closely allied in structure and situation, have perfectly different endowments. I have attempted in Sect. XVI. to apply this principle to the known involuntary influence of Sensations and Emotions on the different functions of the body; and to assign a use for the plexuses and ganglia, and other complex arrangements, of the Nervous System, through which the influence of these mental affections must be transmitted, with rather more precision than other authors have done.

I am fully sensible, however, that this work has very little claim on the public attention, on account of the importance either of new facts or new views contained in it. It professes to be only an unprejudiced statement of the principal ascertained facts, and inferences from those facts, which constitute the science of Physiology, arranged on as systematic a plan as the state of the science admits; and adapted, to the best of my judgment, in the comparative fulness of details on the different branches of the subject, to the consideration of young men who study Physiology as part of their preparation for important practical duties.

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OUTLINES OF PHYSIOLOGY.

CHAPTER I.

PRELIMINARY OBSERVATIONS, ON LIFE AND ORGANIZATION.

In treating of Physiology, we first consider the living human body when fully formed, in the adult state, and in the full enjoyment of health; and endeavour to deliver the history and explanation, so far as is yet possible, of all that takes place in it, different from what takes place in the dead body. Afterwards we explain the manner in which the body gradually attains to the state of perfection in which we first considered it.

But in order to have a distinct understanding of the kind and degree of *explanation* of which facts in Physiology admit, and to avoid misapprehensions and controversies which have obscured the first principles of the science, it is necessary to attend to the following considerations.

The word Life, as commonly used, does not denote an individual fact or appearance, and, in the outset of the inquiry, cannot be *defined.* It is applied to a certain assemblage and succession of phenomena, which are seen in a great variety of the objects that surround us, and distinguish them from the other objects of our senses. When

these phenomena are examined throughout the whole of Nature, it is found that the most general and characteristic of them is, the continued *appropriation* and *assimilation* of surrounding matter, which we call *Nutrition*; a process which maintains a certain definite structure called *Organization*,—which originates, in all cases that can be satisfactorily observed, by *Generation*, *i. e.* by derivation from a previously existing similar structure,—and terminates by *Death*, *i. e.* not only by cessation of the phenomena in question, but by gradual destruction of the structure exhibiting them, and resolution of the elements composing it into other combinations, presenting no such phenomena.

Having given this general *description* of what are called Living Bodies, we next observe, that many of the phenomena exhibited by these bodies have been found to be not only inexplicable by, but manifestly inconsistent with, the mechanical and chemical laws that regulate the changes, and have been inferred from the observation, of other departments of Nature. In so far as we can ascertain this to be the case, we say that these phenomena are effects of the *Vital Principle*, or of *Vitality*; and that is our *definition* of these terms. They are the general expression for those changes occurring in living bodies, which we judge to be peculiar to them; and stand in the same relation to the science of Physiology, as the terms Chemical Affinity, Electricity, Heat, Light, to other departments of Physical Science.

Thus defined, the notion of Vitality is not only admissible in Physiology, but is that which entitles it to the name of a separate science. Those physiologists, accordingly, who object to the substantive term, Vitality, or Principle of Life, are obliged to use the adjective *Vital*, which conveys the very same idea. And all that has been

stated by Magendie and others, as to the dominion of merely physical laws over living bodies, tends only to limit and define the departments of the animal economy, in which the strictly vital phenomena are observed, not to invalidate what has been said as to their reality and importance.

This notion of Vitality, extending to all classes of organized beings, has no connexion whatever with the notion of Mind, as distinguished from Matter. The phenomena from which the latter notion is deduced, are the characteristic mark of the Animal Creation only; and require the admission into the Physiology of Animals, of a class of facts, and a kind of evidence, that have no place in any other physical sciences. Neither does any opinion, or conjecture, that can be formed concerning the essential nature of Vitality, affect the conclusions in Natural Theology, which are drawn from physiological facts; because these conclusions do not rest on the mode in which Vitality is thought to be communicated to living beings, but simply on the observed adaptation of means to ends, in the economy of living beings.

In regard to the physical structure of organized beings, as distinguished from inorganic matter, the following general facts are the most important to be kept in mind.

1. The elements which enter into the composition of these bodies, although they are the same as, in the inanimate world, form various crystalline compounds, never take the form of crystals, so long as they are component parts of the structures in which vital action is going on, or which are capable of assuming it.

2. They take, nevertheless, perfectly definite forms, which are generally rounded, and these, on examination, appear to be generally resolvable into membranes, fibres, globules, and cells; and cavities of various form and size are always found in their interior.

3. These cavities, as well as the smaller cells, always contain fluids, a part of which, during the living state, is always in motion.

4. These fluids appear, on examination, to be quite distinct from those found in inorganic matter ; they contain the same essential elements as the solid parts of the organized bodies, with the same peculiarities as to the mode of their combination, and both are incapable of being formed artificially, by any known mode of bringing together the elements composing them.

5. These *organic compounds*, solid and fluid, are all formed of a number of chemical elements ; they always contain carbon, hydrogen, and oxygen ; sometimes in the vegetable kingdom, and almost uniformly in the animal, they contain nitrogen also ; and with these, certain earthy and saline matters,—(such as carbonate and phosphate of lime, muriate of soda, &c.), are always so combined, that a portion of these may always be detected in the smallest particle of the compound that can be examined. The ultimate atoms, either of the elements themselves, or of their simpler combinations, so long as they form part of these organic compounds, are always prevented from so aggregating together, as to form those less complex and generally crystalline compounds, to which, in other circumstances, they uniformly tend ; or, as Dr Prout expresses it, the vital action by which alone organic bodies are known to be formed, is always attended with a principle of Self-Repulsion, in the ultimate particles either of the elements, or of the simpler combinations of elements, which go to their formation.

6. These organic compounds, after the phenomena of life have ceased,—in most cases after they have been separated from the living structure in which they are found, —are always liable, though with very various rapidity, to

spontaneous decomposition, if placed in the same circumstances as to heat, air, and moisture, as in the living structure itself. The products of this decomposition are, in a few cases, the elements themselves of which these compounds consist, but much more frequently simpler binary or tertiary, and often crystallizable combinations of those elements. Whether in the course of this decomposition, a fresh formation of organized globules, or even of the lowest orders of vegetables and animals, by *equivocal generation*, can take place, (as is confidently maintained by Turpin and others), is not yet fully ascertained. But the microscopical observations of Ehrenberg and others, make it probable that the principle "*Omne vivum ex ovo*," is applicable even to the lowest of organized beings; and that the phenomena, apparently the most adverse to that principle, are to be explained simply by the known, though inconceivable, rapidity with which the ova of these lowest organized beings may be multiplied.

7. The symmetrical forms which organized bodies assume, differ from crystalline forms, not only in never presenting plane surfaces or angles, but likewise in always containing within them more or less variety of materials, essential to their structure, instead of presenting internally a homogeneous appearance.

8. These symmetrical forms are always gradually developed, and this development always begins, not by *evolution* of an embryo, originally a miniature of the body to be formed, but by *epigenesis*, or thickening of the layers of a granular membrane originally homogeneous, and gradual transformation of these into the different organs composing that body.

9. In examining the variety of organized forms which are thus developed, certain general rules are found to be

followed by Nature, the knowledge of which has acquired the form of a science, and the name of Morphology. But this science is a branch of Natural History rather than of Physiology, although it belongs to Physiology to point out the adaptation of the structure of each living being to the circumstances in which it is placed, and the purposes it is to serve.

10. The various organized forms which the animal world presents, have been most successfully arranged by Cuvier, in the four great classes of Vertebrata, Mollusca, Articulata, and Zoophyta; in the first three of which, all the portions of the external form are disposed symmetrically on each side of an axis; in the last, circularly round a centre. But the microscopical observations of Ehrenberg have shewn, that the order Infusoria of Cuvier's arrangement, instead of remaining in the Zoophyta, should be placed as high as the Mollusca.

Some have conjectured that the phenomena of Life, as they are seen only in bodies thus organized, are merely the natural effects of organization; or, as some have attempted to express it more precisely, of some peculiarity in the combination of the elements, or in the form which they assume, or in both, there only existing.

If this hypothesis were established, Physiology would take its place as a department of Chemistry or of Mechanical Philosophy; but in order to establish it, the facts which appear most clearly peculiar to, and characteristic of, living bodies, must be explained in a manner of which we see at present no prospect. It is certain that, in every instance in which organization can be distinctly traced to its origin, Vitality, defined as above, is found not only to precede it, but to be essential to its development. We cannot assert that the combination of chemical elements, which exists in organized bodies, can be

the cause of the phenomena of Life in any one animal, unless we could produce that combination artificially, or see it produced naturally, without the intervention of any already living body, and then find the vital phenomena to result. And we cannot assert that the form which organized matter assumes, determines it to exhibit any particular vital phenomena; because we know that "the matter from which all animal forms are produced, is at first almost without form," the germ of all animals, so far as has been traced, certainly of all vertebrated animals, being merely a round disk of homogeneous matter, with no difference of form corresponding to the difference of the animals. Organization, therefore, appears, from all that we yet know, to be one of the effects, not the cause, of vital action, as above defined; and it is equally unphilosophical, in the present state of our knowledge, to refer vital action to organization, as it would be absurd, in the present state of our knowledge, to attempt to form living bodies out of the inanimate substances around us.

Others have formed the supposition of a *material substance*, such as an ethereal or subtile fluid, superadded to organization during life, and producing the phenomena of life; but this idea is both unsupported by evidence, and useless in the explanation of facts.

Setting aside both these hypotheses, we hold that all physiological inquiries are intended only to ascertain the conditions under which the various phenomena of Life take place, and to describe and refer to general laws those phenomena themselves. All such inquiries naturally terminate in a reference to certain *Laws of Vitality*, or ultimate facts in this department of Nature; just as the investigation and explanation of phenomena in the inanimate world terminate in a reference to certain Laws of

* Baly's translation of Muller's Physiology.

Motion, of Gravitation, of Chemical Affinity, &c. So general and abstract a term as Vitality, or Vital Force or Energy, is of little avail in any physiological discussion: but the Vital Properties or Powers, and the conditions of their existence, are subjects of more precise knowledge, and are the ultimate facts in the science. Of such first principles we can give no other account, than that they depend on the will of the AUTHOR OF NATURE; but the determination of such first principles is the main object, and the applications of them constitute the details, of all sciences; and every science is thus conversant with principles *peculiar to itself*.

All sciences prosecuted by human beings must be held to be subject to that law of the human mind, by which we infer the existence of Power, or of an efficient cause, from the observation of changes in the universe around us; and each science, and perhaps no one so remarkably as Physiology, contributes to give us more precise information as to the existence and attributes of this First Cause, by enabling us to perceive the adaptation of means to ends, in the laws by which these changes are regulated.

In this, as in other sciences, the general laws of nature can only be ascertained *analytically*, i. e. by the slow process of observation and comparison of individual facts; but when they have been ascertained, even partially, in this way, the information acquired is more quickly and easily communicated to others, by stating some of these principles in the outset, with short and simple illustrations, and then tracing the facts which constitute the details of the science *synthetically*; as originating, in part at least, from the operation of the laws first laid down, and then related to each other as physical causes and effects.

The science of Physiology appears sufficiently advanced to be taught on this plan. The physical causes, or conditions requisite for the performance, of each of the functions, will thus appear, in part at least, from the subjects discussed immediately before it, and its final causes or uses, from those discussed immediately after it ; and several advantages seem to arise from this arrangement, particularly in a course addressed to students, who have already acquired a considerable knowledge of Physiology in the course of their anatomical studies ; but have not been accustomed to regard the functions of the living body systematically, or as connected into a perfect whole.

It seems, indeed, equally expedient, in giving a systematic account of the Animal Economy, to follow the order of dependence of the different functions on each other, as it is, in explaining the actions of a machine made by art, to begin at the point where the moving power is applied, and follow the succession of movements downwards, until we come to that by which the desired effect is produced.

The most general of the laws which regulate the economy of animals, appear to extend throughout the whole range of creation ; and all the phenomena of Life, as occurring in Man, may be illustrated by the corresponding phenomena, at least in the different divisions of the vertebrated animals ; and are indeed imperfectly understood in any one class of animals, unless our views are extended to the provisions for the same objects, under the various conditions presented by the circumstances of other classes.

CHAPTER II.

OF THE MOST GENERAL LAWS OF VITAL ACTION.

It is still supposed by many, that all those movements of fluids in the interior of organized bodies, which are peculiar and essential to the living state, as well as the exercise of their power of locomotion, are produced by the contractions of living solids; and it has been also supposed that those movements, modified by the structure of the solids containing the fluids, are sufficient to explain, according to the ordinary laws of chemistry, all the chemical changes which are essential to the nutrition of living animals; or if not, that the peculiarities of those changes may be ascribed to the varied powers attributed to the Nervous System. The properties of Irritability and Sensibility, therefore, or, in more general terms, of Vital Contractility and of Nervous Agency, have been regarded as the only strictly vital powers to which physiological facts in the internal life and nutrition, as well as in the external movements and faculties of animals, should be referred; and the different vital powers enumerated by Bichat and others, are in fact only different modifications, and some of them only supposed modifications, of these powers.

But it may now be confidently asserted, that this generalization is premature and erroneous, especially in two points; 1. Because there are movements, peculiar to the fluids of living bodies, not referable to the impulse of their contracting solids; and, 2. Because there are chemical changes, peculiar to living bodies, which cannot be

explained by the movements of their fluids, by the structure of their solids, or by the influence of their nerves. It is therefore proper to take a more general view of vital actions, of the conditions under which they take place, and the different powers which they seem to indicate, before treating specially of the vital contractions.

In taking this general view of the subject, we may without presumption first set before us the *purposes of vital action*, *i. e.* the objects which are to be accomplished in the maintenance of organic structures, by means of the powers impressed by Nature on the different forms of organized matter, and of the arrangements observed by her in the formation of organized beings.

In the case of vegetables, the only objects appear to have been, to maintain the infinite variety, and provide for the successive reproduction of those living structures themselves, in such forms and situations, and at such times, as are requisite for the different uses which vegetables serve to the various orders of animals, for their nutrition, their respiration, their protection, and the gratification of their varied wants, and capacities of enjoyment.

The leading peculiarities of the living actions of vegetables, as distinguished even from the organic life of animals, qualify them for this office. They have the power, under conditions to be afterwards mentioned, of appropriating to themselves carbon, as well as hydrogen and oxygen, from the atmosphere, and therefore of purifying the atmosphere, and at the same time applying to their own nourishment inorganic as well as organized matter. If they had not this power, two results would probably follow; first, that the atmosphere would gradually become so loaded with carbonic acid as to be unfit for animal life; and secondly, that vegetable life, dependent entirely as it would in that case be on previously organized matter,

could not be maintained in sufficient quantity for the nourishment of animals, and the materials of the whole organized world would gradually pass into the form of inorganic matter.

Farther, the economy of vegetables is fitted for their office of constantly converting inorganic into organized matter, by this peculiarity, that their nutrition is maintained without any such function as the interstitial absorption of animals, and necessarily involves, during the whole time that any living actions are going on, continual additions to their substance.

In the case of animals, it is obvious that those functions in which Mental Acts are essentially concerned, which establish the relations of external objects to a sentient being, and invest this being with more or less of voluntary power over the surrounding world, are the main objects of Nature in their construction and maintenance. These functions are all fitted to be *sources of pleasure* of various kinds, and in various degrees; and the provisions of Nature for the infinite extension and incessant reproduction of sentient pleasure, over the whole surface of the earth,—for the extension of the powers and capacities of enjoyment in the ascending scale of animals,—and for the higher mental operations and more varied occupations of the human race,—are evidently the main objects to which the laws and arrangements not only of animals, but of the whole organized creation, and of much of the inanimate world, are adapted.

We thus see the essential importance of the distinction drawn by Bichat and others between the functions of Organic and those of Animal Life;—*i. e.* between those which take place in the natural state, without the intervention or consciousness of Mind, and alike in animals as in vegetables; and those in which some act of mind is

essentially concerned, and which constitute the characteristic of animals. But although this distinction should always be carefully kept in mind, yet it cannot be taken as the basis of an arrangement of Physiology; because mental acts, and bodily changes connected with them, are not merely *superadded* to the organic life of animals, but are intimately connected or interwoven with it; forming, in the adult state of all but the very lowest animals, part of the conditions necessary to the maintenance of the quantity, and of the vital qualities, of the nourishing fluid on which all the organic life is dependent.

Another object in the constitution of animals is essentially different from any which the economy of vegetables includes, viz. the provision for repressing the numbers of the animal species themselves, which would otherwise become excessive, in proportion to the limited extent of the vegetable world, on which their nutrition is directly or indirectly dependent.*

Hence many tribes of animals are formed by nature to seek for gratification and find sustenance in the destruction of others; and their structure and economy, as well as their appetites and other mental acts, are adapted to this chief end of their existence. The same difficulty presses on the human species, and is the main cause of many of the evils with which all human societies have to contend, although it is only of late years that this principle has been distinctly recognised. The means which Nature has furnished, and the degree of efficacy which she has granted to human wisdom and foresight, for the correction of those evils, are beyond the province of Physiology, but may be noticed as the bond of connexion between this science and that of Political Economy.

* See Roget's Bridgewater Treatise, vol. i. p. 45.

We next observe, that, for the attainment of these objects, the laws of Nature seem absolutely to require that certain *general conditions* shall in all cases be observed.

In particular, as all living bodies are essentially dependent on the continued process of Nutrition mentioned above, the conditions necessary to the maintenance of this process must be regarded as the most general and fundamental Laws of Vitality ; and the following general laws or conditions of Nutrition, and therefore of all other Vital Actions, appear to have been fairly deduced from observation of all living beings. To several of these the term Vital Stimulus has been applied by some, but that word is generally used in a more limited and definite sense, and the more general term here used is therefore preferable.*

1. In the order of things now established on earth, in by far the greater number, if not the whole, of living beings, life springs only from life (*i. e.* from the previous life of others of the same species), and is maintained only by the previous life of other organized beings ; the materials of the nourishing fluid, both of animals and vegetables, being always in part furnished by previous organized structures ; and these are always reduced to a fluid state by water, taken in along with them.

The higher or more complex animals derive much of their nourishment from animals lower in the scale, and from vegetables ; and the assimilation of the materials composing these may be said to begin in those simpler structures. Vegetables, as already stated, derive much of their nourishment from the carbonic acid of the atmosphere ; but much of that acid is furnished to the at-

* See Baly's translation of Muller's Physiology, p. 31.

mosphere by living animals, so that all the classes of living beings, in the present state of things, seem to aid in nourishing one another.*

2. The crude materials furnished from without are never applied directly to the nourishment of any organized structure, but are always combined with, and *assimilated by*, matters furnished by previous actions of the organized structure into which they are taken; and are thus fitted for its nourishment. This Assimilation, by means of a previously existing product of vital action, is a general law of the maintenance both of animals and plants, although Digestion, such as takes place in animals, will appear to be a secondary law, imposed by the peculiar conditions of their existence only.

3. Another essential condition of vitality is, the exposure of the nourishing fluid of each organized structure to the Air, in order that oxygen may act upon, and probably be absorbed into it, and carbonic acid and other volatile matters be evolved from it.

In the nourishing fluid, which has been acted on by the air, a substance is always found in large quantity, and nearly of the same nature in different plants and different animals, viz. of the nature of gum or sugar (*i. e.* a combination formed chiefly of carbon and water) in vegetables, and of albumen in animals, out of which, in the different parts of the organized frame, a great variety of deposits appear to be subsequently formed.

4. There is great variety in the different orders of living beings, and often in the different states of the same, as to the rapidity with which the supply and exposure to the air of the nourishing fluid, necessary to the maintenance of the vital actions, of which they are

* See Prout's Bridgewater Treatise, p. 470.

respectively susceptible, is kept up; and the general law is, that the more rapid the supply, and the more frequent its exposure to the air, the greater is the energy of vital action, and the variety of vital phenomena, and the more immediate the dependence of vitality on these conditions; therefore, the shorter the endurance of life when these are withheld. On the other hand, the slower the necessary supply of nourishment, and the slighter its exposure to air, the less energy and variety of vital action are in general observed, but the greater is the endurance or tenacity of life, *i.e.* the longer will the faculty of resuming vital action be preserved, after those conditions are withdrawn. These differences are seen in different animals, especially in comparing the warm and cold blooded; in different ages and states of the same animal, especially of those which hybernate; and still more in the different states of vegetables, *e.g.* in seeds or bulbs as compared with perfect plants.

5. All vital action is equally dependent on Heat, as on the other conditions now stated; it is seen only within certain limits of temperature, and within these limits is excited by a rise and depressed by a fall of temperature; the amount of change being more effective, in either way, than the absolute degree of temperature which may be applied. The necessary limits of temperature vary in different classes and states of living beings, and the influence of heat resembles that of air in this respect, that the greater the amount and variety of vital action, the more immediate is its dependence on the maintenance of the usual temperature. Thus animals are more easily killed by cold than vegetables,—warm-blooded than cold-blooded animals,—those in a state of activity than those in a state of torpor,—perfect animals than eggs or pupæ,—perfect plants than seeds or bulbs; and nearly the

same gradation is observed as to the injurious effects of excessive heat.

6. Vital action is also subjected to a remarkable influence from Light. The power of vegetables to decompose the carbonic acid of the atmosphere, and to fix its carbon, and acquire the green colour, is essentially dependent on this agent; and its effect on the colours of animals, and on the growth and development of young animals, though not so well understood, is illustrated by several facts. The effect of Electricity, and of several Poisons, on all vital action, is also to be regarded as an ultimate fact.

7. The fundamental vital action of assimilation and nutrition is in all cases attended with the formation of certain substances, which act as poisons if retained, and which are therefore uniformly *excreted* from the system, or at least from the nourishing fluid. The carbonic acid, thrown off from all living beings, the bile, urine, &c. of animals, and the proper juices, resins, and oils of vegetables, are of this kind.

As the reception of nourishment into living bodies is connected with a continual process of deposition or Nutrition, so the Excretions from the animal body are believed to be connected with a continual interstitial Absorption; but the case of vegetables shews that such absorption is not a necessary prelude to excretion. There must evidently be certain general laws which determine the noxious qualities, and the expulsion of certain compounds, as well as the nutritious qualities, and appropriation of others, although the same chemical elements are contained in both; but no such general principles have as yet been clearly ascertained. In the excretions, the chemical elements are disposed to form crystalline compounds; but whether this is because they have escaped

from the dominion of vital laws, or whether they are excreted because they have become fitted for forming such compounds, is uncertain.

8. All vital action is only of temporary duration in any organized structure, and its gradual extinction by the mere progress of time, is always attended by the same kind of change in the condition of the structure, viz. a gradually increasing proportion of the *earthy* constituents of the solid textures; with which a slower and more languid motion of the fluids, and a gradual deficiency of the vital act of nutrition, are always connected.

The general facts now stated are observed *wherever living structures are maintained;* they appear to be the essential conditions, and characters, of the organic life of all living beings.

When we understand the general objects for which Vitality is given to so large a portion of creation, and, at same time, the general conditions under which these objects can be fulfilled, we can easily perceive that a living body must consist not only, like inorganic bodies, of *parts*, similar in structure and properties to each other, but of *organs*, differing from each other in appearance and properties, but all conspiring to maintain the natural condition of the body in which they are found; and that the Physiology of the whole body resolves itself into the study of the functions of these different organs. And when we take farther into account the external circumstances in which each tribe of animals is placed, and the part it is destined to fulfil in the world, we can often distinctly understand what have been called the whole *conditions of existence* of each animal, *i. e.* the purposes to be served by the construction and by the vital action of all its organs; or by the modification, in its case, of the general construction of the class of animals to which it belongs;

and therefore perceive the adaptation of the organs to their destined ends.

Thus, the necessity for previously organised matter to maintain the nutrition of animals, combined with the intention of bestowing on them the faculty of locomotion, involves the necessity for appetites and instincts, and nervous and muscular powers, and organs of prehension, deglutition, and digestion, varying according to the circumstances, and the use in the general economy of nature, of the different tribes of animals. The necessity for previously existing animal fluids, to assimilate all nutritious ingesta, points out the use of several of the secretions, and one of the uses of the circulation, in the more complex structures. This condition, essential to the nutrition of living bodies, explains also the use of those various provisions, included under the head of generation, by which each parent animal or plant furnishes to the embryo a supply of matter already assimilated to its nature, until, by this supply, its own organs are developed and fitted for their office. It is to be observed, however, that this condition could not have been fulfilled at the beginning of the existence of the *first* individual of any species. The formation of an egg, with its requisite store of nourishment already prepared for the embryo it contains, without the previous existence of a parent bird to form that store, or the development of the embryo of any of the mammalia, without a living uterus to lodge and nourish it, would be as great a miracle as the formation of a perfect animal out of inorganic matter. Yet it is known that the animals now existing on the earth's surface were not its first inhabitants. And these considerations also shew, beyond all doubt, that the origin of every species of living being, now found on the earth, must have been given, at no very distant period, by an exercise of Power superior to, and independent of,

the laws on which their existence and continuance now depend.

Again, the necessity of the exposure of the nourishing fluid of all living bodies to the air, involves the necessity for organs of Respiration, varying according to the circumstances of the different orders of living beings; and the dependence of all vital action on a certain temperature, explains the importance of the various provisions for the evolution and retention of Heat in living bodies.

Farther, the principle above stated, as to the more rapid supply of nourishment, the fuller exposure to oxygen, and the higher temperature which are required by those animals, which exhibit the greater energy and variety of vital action, explains the use and importance of many varieties in the organs of Digestion and Respiration, and in the provisions for the evolution and retention of Heat in different classes, and different states of animals, according to the external circumstances in which they are placed, and the energy of vital action which they are intended to exert; *e. g.* of the differences in these respects between warm and cold-blooded animals, and between animals in a state of activity and of hybernation.

So also, the ascertained principle of the generation of poisons within any living body, in the course of its living actions, involves the necessity for various organs of Excretion, and explains the injurious or fatal consequences which ensue in various diseases, from interruption of these functions; and also from either animals or plants being placed in circumstances in which their ingesta are necessarily mixed with the excretions from others of the same families.*

In so far as Physiology consists in inquiries, "De usu

* See Decandolle, Physiol. Veg. t. i. p. 217, and t. iii. p. 1347; and Macaire in Edin. Phil. Journal, 1833.

partium," it naturally terminates in the establishment of these "conditions of existence" of all living beings But in order to investigate the physical causes of the phenomena of living bodies, our next and most important object is to inquire, what are the Vital Properties, Powers, or Forces by which the vital actions are maintained? We cannot suppose that the power of contraction in living solids is essential to all vital actions; *first*, Because in the commencement of the existence of living bodies, as will afterwards appear, vital actions take place, not only prior to the existence, but essential to the formation of any contracting solids; and, *secondly*, Because there is no evidence of contractions of living solids being concerned in the ordinary nutrition and growth of vegetables, nor indeed of the lowest of the beings commonly ranked as animals, such as the sponges. That we cannot suppose the structure of the vessels or cavities in which the nutritious fluid is contained, to be the cause of the difference in the products formed from that fluid in the different parts of organized bodies, will appear from facts to be stated under the head of Nutrition and Secretion. That we are not entitled to suppose any agency of Nerves to be essentially concerned in producing these phenomena of organic life, will also appear from facts to be then stated; and especially from this leading fact, that all these phenomena take place in vegetables; where we not only cannot detect nervous matter, but have no good reason to infer its existence, because the only phenomena which we *know* to be connected with it in animals, do not exist in plants.

But two strictly vital powers (according to the definition above given), appear to be indicated in all such vital actions, viz. 1. Vital affinity, by which the elements of the nutritious matter must be thrown into the peculiar combinations necessary for forming the organic com-

pounds, and restrained from entering into those other combinations to which their fermentation and putrescence shew that they are prone as soon as life is extinct;—a power which supersedes and counteracts ordinary chemical affinities in living bodies, as completely as vital contractions counteract gravitation or the inertia of matter; and, 2. Some moving power peculiar to life, in all probability of the nature of Attraction and Repulsion, by which the particles of that matter must be moved in the directions, and to the extent necessary for these combinations.

That such a moving power, independent of impulse from the contractions of living solids, acts habitually at insensible distances, on the particles of the fluids of living bodies, will be generally admitted; and that, in some instances, movements obvious to the senses are effected in the same manner, seems sufficiently established by the following facts.

1. Certain living bodies, such as sponges, the larvæ of Batraciæ, and many of the lower classes of animals, produce regular and uniform *currents* in the water in which they live, moving in definite directions; in many instances it is believed that movements of minute bodies, called ciliæ, are the causes of these currents; but in some, no movements, even of ciliæ, are seen to accompany the currents, and even where such movements exist, it is often doubtful whether they are adequate to their explanation.*

2. In certain of the fluids of many plants (milky juices, in which minute globules are suspended), uniform and regular movements have been accurately observed, to

* See particularly Grant in Edin. Phil. Journal, vols. xiii. and xiv. Sharpey, Art. Ciliæ in Cyclop. of Anat. and Physiol. Raspail, Chimie Organique, § 764, *et seq*, and § 582. Lister in Phil. Trans. 1834, p. 377, 379.

which the name of Rotation has been given in the case of the cellular plants, and that of Cyclose in the vascular plants; which are unaccompanied with any perceptible motion of ciliæ, and are not only unattended with any visible contractions of the cells or vessels containing those fluids, but are of a nature which no contractions of these solids appear capable of producing,—particularly in the common case, where the currents in these fluids follow opposite directions in cells or vessels, which are so closely contiguous, that any movements of the parietes of one must necessarily extend to those of the others. And similar phenomena are distinctly seen within the translücent bodies of some of the lowest animals, particularly the Sertularia and Tubularia.*

3. It will afterwards appear that, in the fœtal state of animals, portions of the semifluid matter from which the embryo is nourished, are moved in various directions, and assume determinate forms, before the heart acts, or any contractile vessels are formed.

4. It will also afterwards appear, that when the circulation in the minute or capillary vessels of animals is carefully observed, the globules of the blood are found to exhibit certain movements during the living state, which have never been satisfactorily referred, either to mechanical principles, or to any contractions of the living solids; and the same observation applies to the *diffuse* circula-

* See Schultze in Biblioth. Univ. t. xxxvi. Amici in Ann. de Chimie, t. xiii.; and Ann. des Sciences Naturelles, t. ii. Schultze, and Mirbel and Cassini, in do. t. xxii. Agardh in Bulletin des Sciences Naturelles, t. xi. Raspail, do. t. xii. Le Baillif, do. do. Donné in Ann. des Sciences Naturelles, t. ix. Meyer, do. t. xviii. Lister, in Phil. Trans. 1834, p. 365, 367, 377. And particularly Du Trochet in Ann. des Sciences Naturelles, t. ix., whose observations seem distinctly to shew, that the power which causes this motion acts in the way of Attraction and Repulsion, between the particles of the fluids and those of the granular membrane lining the stem.

tion seen in many animals, low in the scale of beings, whose blood is not confined to vessels.

5. Many phenomena presented by the blood of animals, when drawn from their vessels (which will be afterwards considered), shew that its component parts have relations to each other, which soon cease after it is drawn from the body, and which can be designated only as vital attractions and repulsions.

6. Many of the phenomena of local determinations of blood in health and disease, to be afterwards mentioned, when compared with the known properties of the blood-vessels, seem clearly to indicate, that the flow of blood in the smaller vessels is influenced by causes independent of any contractions either of the heart or bloodvessels.

7. It will afterwards appear, that no cause can be assigned for the appropriation of certain of the materials contained in the compound blood, and the rejection of others, in each texture and organ of the body, unless we suppose that there are certain attractions and repulsions peculiar to the living state.

8. A similar observation may be applied to several facts to be afterwards mentioned as to Absorption in living bodies, and to the motion of the fluids in the lymphatic vessels.

Attempts have been made to refer all these movements, and changes of movement, in the fluids of living beings, to simply physical principles, particularly to the principle of Endosmose and Exosmose, *i. e.* to the tendency of different fluids to attract and penetrate each other unequally, according to known physical laws, through the intervention of a permeable membrane, and thereby to acquire motion in a definite direction.* But although it is certain that this physical principle must act, in a certain degree, as a cause of motion in the fluids of liv-

* See Power, in Cambridge Phil. Trans.

ing bodies, it is quite certain that the endosmose and exosmose often exist, even in organized structures, where no strictly vital changes follow; that several of the vital phenomena just enumerated take place where the conditions of the endosmose and exosmose are absent; and farther, that these and all other vital phenomena are liable to great and often sudden change and modification, from various stimuli and sedatives, from poisons, from injuries, and, in the case of animals, from affections of the nervous system,—which have no such effect on this or any other simply physical principle; and therefore, we are entitled to set aside this explanation as inadequate.

The vital attractions and repulsions, which seem to be the chief causes of the phenomena in question, are probably in a great measure the effect of those vital affinities by which the composition of the fluids of living bodies is continually altered, and the solids nourished. But some of the facts to be afterwards considered will appear to indicate a principle of movement in the animal fluids, independent of chemical changes, as well as of mechanical impulse.

The vital powers thus illustrated, appear to be in operation wherever living structures are maintained; and in the nourishment and growth of vegetables, and of some of the very lowest animals, there is no distinct evidence of any other powers being concerned. But in certain parts of the economy of all animals, there are indications of other vital powers. The moving power afforded by *vital contractions of living solids*, appears to be a necessary part of the economy in all but the very lowest orders of animals, for two distinct reasons, both resulting from the destined office of animal bodies as the residence of mental phenomena, and the instrument of mental powers. 1. The

complexity of their structure, and necessary separation of their different organs, which are to be maintained by the same nourishing fluid, are so great, that without the aid of such impulse, the other moving powers existing in the body are inadequate to the extent of motion which that fluid must perform. 2. The power of *spontaneous locomotion* is necessary, both for their own support, and for the ulterior purposes which they are to serve in the world; and this function, wherever it exists, is performed by means of vital contractions of organized solids. Hence certain laws of vital contractions, although apparently of less general existence among living beings, are yet, in the physiology of all the higher classes of animals, equally essential and fundamental principles.

The different modifications of what we call Nervous Agency, will afterwards appear to be the means by which the physical changes of living animals are placed in connexion with mental phenomena, and subjected to the control of mental acts; but it is not proved that they are essentially concerned in any of the strictly organic functions, and without proof it appears unphilosophical to assume any such principle.

Thus it appears, that the agency of the following distinct vital powers in the economy of animals must be admitted, in order to explain the essential differences of the phenomena there seen, from those of inanimate matters,—Vital Attraction and Repulsion, Vital Affinity, Vital Contractility, and Nervous Agency. Of these, we must admit that the two first, although the most general in their operation, are the least understood.

Two important general facts may be added here, as well ascertained in regard to all manifestations of Life.

1. The power of exhibiting the phenomena of Life may, in any case, *remain latent* a certain time, not only

without any act of nutrition, but without the indication of any vital act whatever. But the period during which this is possible varies from a few minutes, in the case of the warm-blooded animals, to several years in the case of some of the animalcules (as the Rotiferæ and the Vibriones), and to many ages in the case of the seeds and bulbs of vegetables. The general rule seems to be, that, in accordance with what has been already stated, this latent vitality may exist longest in those organized bodies which in the living state present the least variety and energy of vital action; but we cannot assert that this rule is uniformly observed. It was maintained by Mr Hunter, and probably with good reason, that this latent vitality affords the only explanation of the absence of putrefaction, in circumstances often observed, in certain organized bodies, as eggs, bulbs, roots, &c., when no vital changes are actually taking place.

2. The vital principle, or the power of shewing vital phenomena, appears undoubtedly, in various circumstances, to be communicated or transferred from certain particles of matter to others in their immediate vicinity, as in the cases to be afterwards considered, of the coats of the bloodvessels, both in the healthy state and in the state of inflammation, communicating certain properties to the blood; of any living receptacle preserving this or other animal fluids from putrefaction; or of certain living properties, and peculiar organic forms, being given to the ingesta into the stomach during their passage through the primæ viæ, and the lacteals. Indeed, it is only by this rapid transference of vital phenomena from one particle to another, that we can understand the effects of ordinary stimuli applied to single points, either of muscles or nerves, and instantly extending their influence to a great distance.

CHAPTER III.

OF THE LAWS OF VITAL CONTRACTIONS.

We call the property or power of Contraction, seen in certain of the solids of living animals, Vital, because we are satisfied of the failure of all attempts to refer it to chemical or mechanical principles; and we regard it as an ultimate fact in Physiology, because, although other functions of the living body furnish the conditions necessary to the maintenance of the organic structures in which it resides, yet we shall find that no other functions afford any explanation of its existence, in the structure so maintained. The following appear to be ultimate facts, or principles, that have been ascertained in regard to this power.

I. It is most distinctly seen, and has been chiefly studied in *muscular parts, i. e.* in parts which consist chiefly of fibrin, and have a fibrous structure; the visible fibres being bound together by cellular membrane into fasciculi, which are generally laid parallel; and being divisible by mere separation into primary filaments of extreme tenuity, which have the appearance, under the microscope, of rows of globules: although it is doubtful whether that appearance is not in some measure deceptive.

This general description applies both to the muscles that are subjected to voluntary efforts of mind, and to some of those that are exempt from such influence, par-

ticularly the heart. According to Dr Hodgkin* the appearance of transverse striæ or resemblance to rows of globules, is not perceptible in most of the muscles of organic life. And in some parts even of the human body, such as the different vessels, some of the excretory ducts, the skin, perhaps other membranes, perhaps the lungs, and still more in lower animals, vital contractions take place in textures considerably different from muscular fibres.

II. The most obvious and striking vital contractions which take place in muscles, are immediately preceded by the application of certain agents, called *Stimuli*, and necessarily *alternate with relaxation*. To the property thus indicated the name of *Irritability* is properly restricted. When this contraction takes place, the filaments constituting the muscular fibres assume a zigzag or waving form, the angles formed being always at the same points, and being generally obtuse, but in the case of very forcible contraction, acute ; the fibres become rigid and elastic ; their strength of cohesion is greatly increased, as appears from the weight which they are then capable of supporting, and it would appear that they have a vibratory motion, consequent probably on successive relaxation of different individual fibres, during the continuance of the contraction ; they often appear to swell out towards their centres, but experiments seem to shew that their real bulk is not altered ; the change being in the relative position, not in the size or distance, of their ultimate particles. The sudden change, and immediate restoration of the relative position of these particles, seems to indicate a peculiar kind of Attraction, followed by Repulsion ; and the extension of this change to the whole

* Appendix to translation of Edwards on Life, p. 443.

extent of a fasciculus of fibres, on irritation of a single point, proves that these vital powers are very rapidly communicated from one particle to another.

Even in the most distinctly contractile parts, as the muscles of the limbs, tongue, heart, bowels, bladder, there are manifest differences as to the facility of excitation, the degree, strength, endurance, and tendency to repetition, of the vital contractions. The rapid succession of relaxation or elongation to contraction, which characterizes what we designate strictly as Irritability, is chiefly seen in the muscles of Voluntary Motion, and in the Heart; and it is in these parts that we see the greatest thickness of muscular fasciculi, and the greatest rapidity, and strength, of muscular contraction. In the Stomach and Intestines the muscular fasciculi are much thinner, their contractions and alternating relaxations extending in the direction of the alimentary canal, slower and more gradual, but the extent of decurtation of which they are susceptible, greater.

In the Bladder and Uterus we see muscular contraction excited by irritation, and often going to a great degree of shortening, but not alternating in the healthy state, with any such rapid and decided elongation; and it will afterwards appear that the Arteries, and probably the Veins and Absorbents, are nearly in the same predicament. In these cases we may apply the term simple Contractility, instead of Irritability. These differences are probably connected with the difference of minute structure noticed by Dr Hodgkin. In the different classes of animals there are still greater varieties in these respects.

Various facts, to be afterwards considered, indicate that there is, in the living body, an *adaptation* of peculiar stimuli to the muscular action of certain organs.

III. There is, farther, distinct evidence of the existence in certain living solids, of a vital Contractile Power, distinguished by these peculiarities, that it requires no stimulus to excite it, and that it hardly, if at all, admits of relaxation, but determines a certain degree of permanent contraction of the parts endowed with it, when no distending cause affects them; which gradually abates after death, but before any decomposition takes place. This property has been called *Tonicity*. It is exemplified in the condition of the sphincter muscles during life, and in that of the arteries when emptied of blood. The extent of its operation in the living body is uncertain; but several circumstances indicate that all muscular parts possess this property, as well as irritability. Thus, when a living muscle is divided, its cut ends retract permanently, and farther than those of a dead muscle. When a limb is permanently bent by an injury, its flexor muscles are permanently retracted, and remain capable of farther occasional contraction; and during sleep, the limbs are in a state of permanent although varied flexion, probably dependent on predominance of the flexor muscles, and implying a certain exertion of their contractile power. The temporary stiffening of the voluntary muscles after death, appears to be a last exertion of this vital power of Tonicity in them. And in several respects this change differs essentially from muscular contraction excited by irritation. Thus it is more directly excited by heat,—it is not excited by galvanism, nor by mechanical irritation, nor does it take place until the excitability by the latter means is nearly or quite extinct; and it is even stopped or prevented by the application of substances, such as common salt, which strongly excite the vital power of irritability in muscles. Yet that it is truly a vital change appears from the tendency to it being lost by muscular

exertion and recovered by rest, from its disappearing before putrefaction begins; and farther, from its being totally prevented in some cases, where death takes place from a sudden and a violent cause, but one which does not affect the organization of the muscles, such, *e. g.* as lightning, or excessive mental emotion.*

IV. The contractions of many muscles are excited, not only by stimuli applied to themselves, or to the membranes investing them, but also, with equal or even greater facility, by stimuli applied to certain Nerves which enter them, or to certain parts of the Spinal Cord, or Brain, provided the nervous communications of these parts with the muscles be entire. Farther, certain injuries of the brain or spinal cord have power, either apparently to increase, for a time, or directly and instantaneously to impair, or even destroy, the vital power of all the muscles. Voluntary acts of the mind act on muscles precisely on the same footing with physical agents of the first class now described, directly exciting contraction; and certain feelings or passions of the mind seem to act in like manner as those of the second class, modifying the contractile power.

These facts have naturally led to much speculation regarding the connexion between the Nervous System and the vital power of the moving solids of the living body.

Two theories on this subject have been so generally adopted in the Schools of Medicine, that, although unsupported by adequate proof, they demand attention.

The first is, that all muscular parts *derive a supply* of some kind of *influence or energy from the brain or*

* See Hunter on the Blood, &c., vol. i. p. 153 *et seq.*, and Prater's Experimental Inquiries in Chemical Physiology, p. 159 *et seq.*, p. 185 *et seq.*, and p. 216.

spinal cord, through the nerves, which enables them to contract, or *renders them irritable.* The second is, that muscles, although not actually drawing supplies of vital power through their nerves, are yet *dependent on nerves for every occasion of the exercise of that power*—all stimuli, which excite muscles to contraction, acting first on the nervous filaments which enter muscles, and through them on the muscular fibres.

To the *first* of these opinions the following appear to be insurmountable objections.

1. Indications, not only of vital movement in general, but more specifically of a vital power of contraction, are a more general fact in nature than the existence of nerves, being seen not only in the lowest class of animals, where the existence of a nervous matter is still doubtful, but also in certain vegetables.

2. The human fœtus has often come to the full size (implying long continued exertion of contractile power in the organs of its circulation) without a brain, and sometimes without either brain or spinal cord; and in all cases, during the growth of the fœtus, various movements, and the formation of different parts, precede that of nervous matter, and the organs of circulation are in full operation, when the larger masses of the nervous system are still very imperfectly developed.

3. The involuntary motions of the organs of circulation have been found by many physiologists to continue vigorous, even in warm-blooded animals, after the removal of the brain, or even of both brain and spinal cord, provided that the exposure of the blood to the air is secured by the substitution of artificial for the natural respiration (which being undoubtedly and directly dependent on the brain, necessarily ceases on its removal). And in these circumstances, when circulation, after some hours,

does come to a stand, it is chiefly, as it would seem, because the artificial is only an imperfect substitute for the natural respiration.

In hybernating animals, even warm-blooded, where the necessity for exposure of the blood to air does not exist, the regular action of the heart has been observed to go on without the aid of artificial respiration, for nine hours after such an injury as destroyed the whole brain and spinal cord. *

4. No interruption of the contractions of the heart, or other strictly *involuntary* muscles, has ever been distinctly observed to be produced by cutting the nerves by which they are immediately supplied,† or by injuring their ganglia.

5. Although the muscles destined to voluntary motion are no longer moved by the will, after the section of their nerves, they continue thereafter to shew their irritability, on the application of stimuli to themselves, or to their nerves below the section, as long as their nutrition and organization continue entire. Accordingly, Dr Wilson Philip found that contractions may be excited by direct and continued irritation in the muscular fibres, fully as long in muscles of which the nerves have been cut, as in those, the communication of which with the brain and spinal cord through the nerves, is entire.‡ It has been stated, on the other hand, by Mr J. W. Earle, that when muscles, severed from their communication with the brain

* Marshall Hall in Phil. Trans. 1832, p. 346.

† The experiment of Brachet, in which section of the cardiac plexus itself is stated to have suddenly stopped the heart's action in a rabbit, is too liable to sources of fallacy, and too much opposed to all others on the subject, to be trusted.

‡ Wilson Philip, Experimental Inquiry, &c. p. 99.

and spinal cord, are stimulated until they lose their irritability, they cannot regain it; and in like manner it was found by Muller, that the irritability of muscles, of which all the nerves had been cut, was found, after some weeks, to be nearly or entirely extinguished.* But in the experiments of Mr Earle it is certain, and in those of Muller it is probable, that the organization of the muscles themselves had undergone a change; and in experiments carefully and repeatedly performed by Dr J. Reid† (and which do not appear to have been known to Muller), it appeared beyond all doubt that, in frogs at least, the irritability of muscles, of which the nerves had been divided, after it had been apparently extinguished by wetting them with a saline solution and galvanizing them strongly, was completely regained after a few days, their organization remaining entire, although their sensibility and voluntary power had been wholly destroyed; which fact seems nearly decisive against the theory in question.

Again, to the *second* of the theories above stated, it appears a sufficient objection to state, that our only reason for supposing an intervention of nerves to be concerned in muscular contraction, is the excitation of that contraction by stimuli applied to nerves. But a conclusion which is rested on this fact, must be limited to the cases in which this fact holds good. Now, there are *many muscles* (probably all those that are not destined in the natural state, to obey any mental act) which, although exceedingly irritable, *are not excitable by mechanical irritation of their nerves*. Even Galvanism, applied exclusively to the nerves of these muscles, has generally failed to excite them; and in the instances where galvanism, so applied, has had some effect, it appears pro-

* Baly's translation of Muller's Physiology, p. 631.

† Transactions of British Association, vol. iv. p. 671.

bable that the nerves acted only as conductors of the galvanism to the muscular fibres themselves.* Farther, if all stimuli acted on muscular fibres only through the intervention of nerves, we should expect to find, that all substances which act as stimuli on muscular fibres themselves, act on them likewise through their nerves. But it has been found, both by Dr Wilson Philip and by Muller, that many chemical stimuli, which are quite effectual when applied to muscles themselves, are wholly void of effect when applied even to the motor nerves of voluntary muscles.† When experience shews, that some muscles are excitable by irritation of their nerves, and others not, and that some of the stimuli of muscles act, if applied to their nerves, and others not,—we cannot acquiesce in the proposition, that nerves furnish a condition essential to the irritation and vital action of muscles in general.

We must therefore set aside both the hypotheses above mentioned; and in so doing, we necessarily limit the meaning of the terms "Nervous Energy, Nervous Influence, Innervation," &c. in reference to the connexion of vital movements with nerves, to a degree of which many of those who use these terms do not seem to be aware.

It remains that, on this point, we acquiesce for the present in the judgment of Haller,‡ as the only generalization yet admissible of the facts known in regard to it, viz. That *the vital power of Muscles is inherent in themselves*, and in no case known to be dependent on Nerves; but that it is liable to affection in two distinct ways, by changes in certain parts of the Nervous System, whether

* See Baly's Translation of Muller, p. 663.

† Wilson Philip on Sleep and Death, p. 101. Baly's Translation of Muller, p. 615.

‡ See particularly Elem. Physiol. lib. 17, sect. 2, § 7.

these are produced by physical or mental causes;—being *directly excited in many muscles,* and *increased or diminished,* or *variously altered,* probably *in all muscles,* by such changes.

That sudden increase, diminution, or even destruction, of vital motions, may be produced by certain physical impressions, made on portions of the nervous system which are nevertheless not essential to these motions, and which may be removed from the body without stopping them, is well illustrated by the experiments of Legallois and of Dr Wilson Philip on the effect produced on the heart's actions by injuries of the brain and spinal cord. In like manner, in experiments by Muller, caustic alkali applied to the cœliac ganglion caused an immediate increase of the peristaltic action of the intestines, continuing long after the application had been discontinued;* although these regularly peristaltic movements are certainly not dependent on the cœliac ganglion, inasmuch as they continue, and may be re-excited when they have ceased, after the mesentery, and all the nervous fibrils passing along it into the intestines, have been divided. All these facts appear clearly to indicate an occasional controlling power, not a necessary vivifying influence.

The corresponding effect of certain involuntary mental acts on muscular movements, requires no illustration. Those causes, physical or mental, acting on the nervous system, which augment the contractile power of muscles, and invigorate muscular motion, have been called Stimuli, but are more properly called *Stimulants;* and the opposite depressing power of such causes, is expressed by the term *Sedative.*

The direct excitation of muscular contraction by changes in the nervous system, is seen chiefly, perhaps exclusively,

* Baly's Muller, p. 664, and 732–3.

in those muscles that are destined to be moved by the will. The increase or diminution of vital power by such causes, is seen chiefly in those muscles that are unaffected by efforts of the will. The essential difference of the voluntary and involuntary muscles seems to depend on the different endowments of the nerves entering them, "qui soli in corpore mentis sunt ministri." And the only ascertained final cause of all endowments bestowed on nerves in the living body, in relation to muscles, appears to be, *not to make muscles irritable*, but to *subject their irritability, in different ways, to the dominion of the acts and feelings of the Mind.*

V. The vital power of muscles is found to undergo remarkable alterations, in consequence of the degree in which it is itself exercised. On this point, likewise, important misconceptions and erroneous theories have prevailed.

The immediate effect of frequently repeated excitation of any muscle, by physical stimuli, is a diminution, or what has been called Exhaustion (although not absolute destruction) of its Irritability; and the same effect evidently results from such repeated or long-continued efforts of the Will, as cause fatigue of the voluntary muscles. But it is by no means certain that all increased action, especially such as implies real augmentation of vital power, observed chiefly in involuntary muscles (whether from changes in the nervous system or from other causes), is necessarily followed by any corresponding depression. The peculiar effect of poisons, such as alcohol or opium, which first augment, and afterwards depress, the action of the organs of circulation, does not, as some have supposed, furnish any proof of the consequences which necessarily result from the mere circumstance of increased ac-

tion itself; and in the case of moderate exercise,—of mental excitement,—and in the course of different febrile and inflammatory diseases,—we have examples of greatly increased action of the heart, without any decidedly debilitating effect on the heart's actions necessarily following. The doctrine of increased action necessary in all cases lowering or exhausting the irritability of muscles, particularly as applied to the involuntary motions, is therefore by no means an established principle.

In so far as the irritability of muscles is diminished by excitement, it is restored by rest; but the supposition of farther increase or *accumulation of irritability from long continued rest*, corresponding to its exhaustion by excessive action, although insisted on by various physiologists, appears to be quite unsupported by facts; and the phenomena thought to indicate such accumulation of vital power, in contractile parts kept long at rest, are explained on other principles. For example, the greater stimulating effect of Heat, applied after cold of some duration, is evidently to be ascribed to the greater amount of change of temperature, which its application then implies.

Although the *immediate* effect of strong excitement of muscles is, in many cases, a diminution of their power, yet the *ultimate* effect of repeated excitement, with intervals of repose, is to augment both the bulk and strength of all muscular fibres, apparently by increasing their vital attraction of their proper nourishment from the blood; and to facilitate the subsequent excitement of moving parts, whether voluntary or involuntary. The applications of this last principle, both in Pathology and Therapeutics, are very important.

VI. The Vital Power of muscles undergoes gradual alterations during the whole progress of life, being most

easily excited, or shewing the greatest degree of *mobility*, in young animals; becoming gradually stronger, but less easy of excitation in adults; and afterwards undergoing a diminution both of strength and of mobility. But as these variations are attended by gradual alteration of the organization of the moving parts, it is probable that the primary change is in the vital affinities, by which these are nourished and maintained, rather than in the vital power, by which they are animated.

The movement of the fluids, in all the higher classes of animals, is in a great measure dependent on vital contractions in certain of their solids, and may be therefore regarded as the first and most important consequence of the exercise of the Vital Power which we have now considered. This subject naturally divides itself into two parts; *first*, the movement of the mass of blood in the heart, arteries, and veins, or the Function of Circulation, as carried on in the adult state of the human body; and, *secondly*, the continual evolution of matters from, and absorption of matters into, the mass of blood, or the Functions of Nutrition, Exhalation, Secretion, and Absorption; to which the Circulation is subservient, and on which all the other functions are dependent.

CHAPTER IV.

OF CIRCULATION.

The conditions already stated, as essential to the fundamental vital action of Nutrition, absolutely require the existence and the motion within every living animal, of a nutritious fluid, supplied from without, so far assimilated by combination with the fluids formed by the living body itself, and regularly exposed to the air. And it appears from recent inquiries, that a circuitous movement is given to this nourishing fluid more generally in the animal kingdom, than was formerly supposed. But it is only in the higher classes of animals that this essential condition of all vital action is fulfilled by means of such a regular Circulating System, as exists in man.

In some of the Zoophyta, there is merely transudation and imbibition ; in others, as the Sertularia, the movement observed is simply a flux and reflux in the hollow stem ; in others, as the Tubularia, it is a circuit around the interior of each of the elongated cells of which the body is composed. There is often no muscular organ, but in many cases there are numerous ciliæ concerned in the process. In tracing the animal kingdom upwards, we find the arrangements for the circulation of the fluids become gradually more complex, not indeed in exact proportion to the complexity of other parts of the structure, but in conformity with the varying circumstances and wants of the different classes. Thus, in the higher Zoophyta and the Articulata, (as in insects,) the usual course of the fluids is forwards, by a dorsal vessel, and backwards by

lateral and inferior passages,—partly vascular, and partly cellular,—a muscular power seems to be possessed by large portions of the vessels, and part of the blood is exposed to the air at many different points on the sides of the animal. In the higher Articulata (Crustacea), and in the Mollusca, there are not only vessels, but one, two, or more hearts, to which the muscular power is nearly confined, there are separate organs of Respiration, and generally a double circulation, *i. e.* all the blood which has circulated through the body, is carried to the respiratory organ, before it is again dispersed through the system. In fishes there is a double circulation, but imperfect respiration by gills, the blood acting on that air only, which is contained in water. In reptiles there is the more perfect respiration by lungs, but a single circulation, part only of the blood that has circulated through the body being sent to the lungs. In the Mammalia and birds only, we find the double circulation, with the perfect respiration by lungs.

The circumstance in the animal economy, which appears chiefly to impose the necessity of a heart and system of circulating vessels, distinct from the other vessels or cavities in the living body, is the appropriation of a separate organ to the office of regularly exposing the fluids to the air; and this again is demanded by such occasion for strength and solidity in certain parts of the frame, as precludes the possibility of free admission of air to the fluids in all parts of the body, such as takes place in some of the lower classes. A complex frame, capable of exertions of strength, and of resistance to injury, a separate respiratory organ, and a regular circulating system, are therefore very generally, if not necessarily, combined throughout the animal creation.* And in all warm-blooded animals, the circulating system is to be

* Cuvier, Leç. i. Art. 4.; and Leç. xxiii. Sect. ii. Art. 5.

regarded as merely the channel of communication between the capillaries of the lungs, where the blood is prepared by the action of the air, for the maintenance of the different functions of life, and the capillaries of the rest of the body, where it is applied to the support of these different functions. The collection and concentration of the blood at the heart are manifestly intended to subject it to the action of a strong muscle, and thereby secure its transmission, with adequate force and precision, through the different sets of capillary vessels; and the juxtaposition of the two portions of the heart, which move the blood to and from the lungs, appears to be merely a matter of convenience;—found in all cases of double circulation, where there is atmospheric respiration, but not when the circulation is double, but the respiration aquatic,—perhaps only because, in this last case, the organ of respiration being necessarily exposed to a stronger and more varying impulse from without, requires a contracting organ appropriated to its own actions.

In treating of the Circulation, we first state the course followed by the blood in the living human body, with the evidence by which this course is demonstrated; and then we consider the nature and efficacy of the agents, by which this movement of the blood is produced.

During the living state, all the blood which is contained in very minute or Capillary Vessels, in every part and in almost every texture of the body, gradually makes its way into Veins, and along them, passing from those that are more numerous and smaller, into those that are less numerous and larger, till it reaches the anterior or right auricle of the Heart, by the venæ cavæ and coronary vein, and distends that cavity. By the contraction

* See Cuvier, Leç. I. p. 49.

of this auricle it is driven into the right ventricle, and by the contraction of this, into the pulmonary artery, by the numerous branches of which it is distributed among the minute capillaries of the Lungs, to be exposed to the air. From these, it again passes along an ascending series of vessels contained in the lungs, until it emerges from them to enter the four pulmonary veins, which lead to the cavity of the posterior or left auricle of the heart. By the contraction of this auricle, simultaneous with that of the right auricle, it is forced into the left ventricle, and by the contraction of this, simultaneous with that of the right ventricle, it is forced into the Aorta, by the numerous branches of which it is gradually conveyed into the capillaries, that pervade the various organs and textures of the body.

That this is the real course of the blood, is proved by various facts, but especially by the following:—

1. By the observation of the successive distention of the venæ cavæ near the heart, of the auricles, and of the ventricles, in living and warm-blooded animals, taking place in the order above stated,—and by the observed passage of the blood through these cavities, in those lower animals that have hearts similarly formed (although single) and translucent.

2. By the observed passage of the blood from the minute capillary arteries into the beginnings of the veins, in the translucent textures of different fishes and reptiles, which have a circulating system similarly formed to that of the higher classes, although single.

3. By the structure of the valves, at the heart and in the veins, necessarily prohibiting, or greatly impeding, movement along the vascular system in the opposite direction from that above stated.

4. By the effect of ligatures, and of punctures made

above and below ligatures, in the larger arteries and veins; the former swelling out and giving a free jet of blood within the ligatures, and the latter beyond them.

5. By the quantity of blood which may be rapidly discharged from a wound below a ligature on the vein of a limb; which is so great as to demonstrate that the vein must have a continual supply of blood from the arteries of the limb.

6. By the effect of injections into arteries and veins of living animals, making their way readily, and easily filling the vessels, when thrown in the direction of the circulation as described, but strongly resisted when forced in the opposite direction.

The structure and actions of the Heart, the chief muscular agent in this process, and the *first* of the powers by which the movement of the circulating fluids in the adult state are effected, first demand our attention. Its oblique position within the pericardium, in the fore part and left side of the thorax,—its irregular conical form, flattened posteriorly,—its division into two parts by the septum, and the form, size, and relative position of the right or anterior, and of the left or posterior, auricle and ventricle,—the termination of the great veins in the auricles, and origin of the great arteries from the ventricles,—the lining of the muscular texture of the heart by two serous membranes, the external reflected from the inner layer of the pericardium, and the internal continuous with that which lines the bloodvessels,—are all supposed to be made known by the study of Anatomy.

The muscular fibres of the auricles of the heart are quite distinct, and easily separable (after long-continued boiling) from those of the ventricles; and the part of the heart which may be regarded as the fixed point or pivot of its movements, is the point between the posterior

groove on its surface and the origin of the aorta, where the muscular fibres, constituting the septum of the auricles, are set upon those which form the septum of the ventricles. The contractions, both of auricles and ventricles, tend to bring all other parts of the heart nearer to this fixed point. The texture found at this point is tendinous; and in immediate connexion with it, are the tendinous rings (partly bony in some animals) which surround the origin of the aorta and pulmonary artery, and the openings between the auricles and the ventricles. From these tendinous parts most of the fibres, constituting the muscular parietes of the heart, take their origin. Those which go to the parietes of the auricles ascend, form loops around these cavities, of various form and size, and then descend to be inserted into other points of the same tendinous rings, and are encompassed at their lower part by more superficial horizontal layers of fibres. Those which go to the parietes of the ventricles have an oblique course downwards, and appear to be reinforced by others which originate in the muscular texture itself, especially along the anterior and posterior grooves, which lodge some of the coronary vessels. The outermost of them converge towards the apex, and, after making a spiral turn round it, pass inwards and ascend along the interior of the ventricles, forming the columnæ carneæ and part of the septum, and arranging themselves in the reticulated form, which is obvious on opening the heart. Others of the fibres descending from the tendinous rings merely form loops around the ventricles, and reascend to the rings. The obliquity of the direction of the fibres is gradually altered towards the interior of the muscular substance, so that about the centre of the thickness of the parietes, the fibres are wrapped round the ventricles nearly transversely; some surrounding both ventricles,

while others detach themselves at the septum, and surround the left ventricle only, making its parietes thicker and stronger than those of the right.

This is a general outline of the disposition of the greater part of the muscular fibres of the heart. At its base the arrangement is more complex, but it is always regular and uniform; and evidently such, that a general contraction of the fibres of the heart shall bring all parts of the heart towards the central point above mentioned, and compress the contents of all the cavities, so as to secure their forcible ejection by the openings there situated.

The valves placed at these openings effectually prevent any reflux of the blood that has been ejected. The structure of the membranous folds forming the semilunar valves, at the mouth of the great arteries, sufficiently indicates their use; for they are attached to the interior of the vessels by curved edges, the concavity of which is turned from the heart, and they must therefore be raised and stretched across the opening by any fluid passing towards the heart, but are laid down along the sides of the arteries by any fluid passing out of it. The tricuspid and mitral valves, which descend from the tendinous rings surrounding the auriculo-ventricular orifices, into the ventricles, and are attached by tendinous cords, partially decussating, to the ends of the columnæ carneæ, appear to fulfil their office, of preventing any reflux of blood from the ventricles to the auricles at the moment of the contraction of the former, in consequence of being subjected to the action of two distinct causes, *first*, they are raised and stretched across the ventricle by the portion of blood which lies, at that moment, between them and the contracting walls of the ventricles, and *secondly*, their lower extremities are pulled together, and the space inclosed within them changed from cylinders to broad and short

cones at that moment, by the contraction of the columnæ carneæ to which they are attached, and which appear to contract simultaneously with the mass of fibres constituting the parietes of the ventricles.*

When the heart of a living warm-blooded animal is exposed, the simultaneous contractions, first of the two auricles, and then of the two ventricles, may be distinguished; but in the natural and vigorous state of the circulation, the former movement (always a comparatively slight one) is hardly over before the latter begins; and the longest pause in the visible motions of the heart is that which succeeds the diastole of the ventricles, and precedes the systole of the auricles.

The successive contractions of the auricles and ventricles are often observed to go on, for a short time, nearly in the usual way, after the heart of a living animal is emptied of its blood, or even removed from the body; so that there is obviously a tendency to the regular succession of these movements, independently of the successive applications of the stimulus of the blood to these parts. Perhaps the peculiar convoluted form of the muscular fibres, already noticed, implying that the columnæ carneæ within the ventricles must be compressed and irritated each time that the fibres exterior to them contract, may be concerned in giving this tendency to a regular succession of contractions; but if so, the contraction of these columnæ carneæ must take place after an interval from the irritation exciting it, and when taking place must extend instantly to the fibres lying exterior to, but continuous with them.

When the ventricles contract, the apex of the heart is not only pulled upwards, but somewhat raised or tilted forwards, it is during this systole of the ventricles, that the

* See Transactions of British Association, &c., vol. vi.

apex of the heart gives the impulse against the parietes of the chest, which is felt, in general, between the fifth and sixth ribs, sometimes higher, hardly ever, in the natural state, lower than this, and which, just perceptibly, precedes the pulse at the wrist.* The projection of the apex of the heart on the contraction of the ventricles, is seen even when the heart is removed from the body of a warm-blooded animal before its actions have ceased, and seems to be sufficiently explained by the disposition of its muscular fibres, and particularly by the irregular cone which they form, being *flattened posteriorly*.

When the ear is applied to the human chest, over the situation of the heart, a dull and somewhat prolonged sound is observed to precede and accompany the impulse of the heart against the parietes above mentioned; and this is immediately succeeded by a shorter and sharper sound; after which there is a short pause, before the dull sound and impulse are renewed. A slighter impulse or succussion, is sometimes observed to accompany the sharper sound likewise. It appears from numerous recent investigations, made chiefly on animals in a state of stupor, but in which the circulation was maintained in full force by the artificial respiration, that the dull sound and chief impulse (as originally stated by Laennec), attend the contraction of the ventricles, and stroke of the apex of the heart against the parietes of the chest; and that the sharp sound and weaker impulse (as was first stated by the late Professor Turner in opposition to Laennec), attend the diastole of the ventricles, and precede, by a short interval, the contraction of the auricles. The cause of the sounds is ascertained (in opposition to the opinion lately stated by Magendie) to be in the heart itself, although they

* See particularly Hope's Treatise on the Diseases of the Heart and Great Vessels, and Transactions of British Association, vol. v.

are rendered more audible by its coming into contact with the sternum and ribs. The first, or dull sound, appears to proceed partly from the contraction of the fibres of the ventricles, but chiefly from the impulse of the blood, moved by that contraction, on their irregular internal surface. The second, or sharp sound, having been found to be altered or suppressed by fixing one of the semi-lunar valves against the side of the aorta or pulmonary artery, seems certainly to depend (as was first conjectured by Dr Gairdner, and afterwards by Dr Elliot)* on the sudden stroke, against those valves, of the columns of blood in these arteries, which fall back at the moment of the diastole, and, but for their intervention, would re-enter the ventricles.†

The contractions of the variously disposed muscular fibres of the different parts of the heart are clearly sufficient to agitate the blood powerfully, and ultimately to eject it by the arteries with great force. The quantity ejected at each systole of the left ventricle seems to be nearly two ounces in an average-sized man, and the space it must occupy in the aorta nearly eight inches. The calculations of Hales, who states the force exerted by the left ventricle of a human heart as equivalent to 51½ pounds, the velocity of the blood leaving the heart as 149.2 feet per minute, and the quantity of blood passing through the heart every hour as 20 times the whole weight of the blood in the body,—although only approximations to the truth, do not appear to be founded on exaggerated data. The velocity of the circulation is also illustrated by the fact, that

* Turner on the Sounds of the Heart in Edin. Medico-Chir. Trans. vol. iii. Elliot de Corde, Edin. 1831, p. 53. Gairdner's Inaug. Dissert. (unpublished). Edin. 1830.

† See particularly Williams on the Pathology and Divisions of the Chest, 3d Ed. p. 170, *et seq.* Reports of Dublin and London Committees in Transactions of British Association, vols. v. and vi.

in the horse, a fluid injected into one jugular vein has been detected in the opposite vein, and even in the vena saphena, within half a minute.*

The diastole, as well as the systole, of the different parts of the heart, especially of the ventricles, is performed with force ; the muscular fibres not merely relaxing as the cavities are distended with blood, but springing back directly after their own contraction is over. The tendency thus given to the formation of a vacuum in the auricles, is one cause of motion of the blood towards the heart along the great veins, where it is subject to pressure from various causes.

Although the different parts of the heart have obviously a tendency to regular and successive movements, independently of the stimulus of the blood, yet experiments prove, that the blood, which is in contact with the inner surface of the heart, acts as a powerful stimulus upon it ; and we cannot doubt that it is by the constant succession of fresh applications to this stimulus, that the nearly uniform succession of the heart's movements throughout the whole of life is maintained.

We can go no farther, in assigning a cause for the natural movements of the heart, than to refer them to the application of this stimulus, and to the property of Irritability, in a high and peculiar degree of intensity, resident in its fibres. We cannot ascribe to the heart any feeling or Sensation, in the performance of these actions, without altering the meaning of these words ; we cannot liken these actions to any Voluntary movements, without overlooking the most essential peculiarities of both ; and we cannot suppose any action of Nerves to be essentially concerned in them, without ascribing to the nerves of the heart endowments, which no experiments or observations prove them to possess.

* Hering, Journal de Progres, &c. t. 10.

The blood is conveyed from the heart to the capillary vessels all over the body by the Arteries; and the properties of these constitute the *second* great agent, on which the phenomena of its motion depend.

These are flexible and elastic tubes, consisting of three coats, of which the exterior, composed of dense cellular texture, is the most distensible and the toughest; the middle, composed of transverse fibres, denser and lighter coloured than those of muscles, is the thickest, strongest, and most elastic; and the internal, on which the blood moves, is very thin and smooth. The arteries are all to a considerable degree extensible, especially in the longitudinal direction; and are of great strength, the smaller branches even more than the larger.

Every small portion of artery, by reason of its elasticity, has nearly a cylindrical form, and the blood therefore passes along a series of descending cylinders, on its way from the heart to the capillaries. But the sum of the areas of the whole of the smallest branches into which any artery divides itself, is considerably greater than the area of the artery itself; although the ratio of this difference has been very variously stated.

The arteries are subdivided into small branches to a great but very various degree of minuteness in the different textures. The smaller arteries communicate or anastomose freely with one another in all parts of the body; the smallest capillaries the most freely of all; and on this account the characteristic effect of ligatures formerly observed, in emptying the portions of artery beyond them, and distending the portions within them, is only distinctly seen in the larger branches.

According to the microscopical observations of Dr M. Hall and of Muller, the vessels strictly called capillaries, in all parts of the body, are of uniform calibre (generally

from $\frac{1}{2000}$ to $\frac{1}{3000}$ inch in diameter), admitting only single globules of the blood, and are the smallest vessels found in the body; such vessels cross in great numbers, in most parts, between the smaller arteries and veins, but it is certain, at least in the translucent parts of cold-blooded animals, that many small arteries turn about and form veins, without having subdivided to this degree of minuteness; and it is probable that the nourishment of some textures, as of muscular texture, according to Prevost and Dumas, takes place without the intervention of strictly capillary vessels.

It has been lately much disputed whether the strictly capillary vessels have really coats, or whether they are merely tracks or channels in the substance of the textures. According to the minute observations of Muller, and other German anatomists, membranous coats of the capillaries may be detected in some textures by injection and maceration, where they are not apparent under the microscope; but it has certainly not been demonstrated that they exist in all; in some parts, as the liver of cold-blooded animals, and according to some, in the spleen even of warm-blooded animals, the blood is hardly confined in any channels, and immediately after death pervades the whole cellular texture. And in almost all parts it is certain, that the parietes of the capillaries, however formed, are so thin as to yield to pressure, and allow of transudation, or even extravasation, very readily in various circumstances to be afterwards mentioned, or according to the expression of Magendie, that, "*Ce n'est qu'a la condition que les liquides seront en harmonie avec les tuyaux, que la circulation est possible.*" *

* Kaltenbrunner in Jour. de Phys. t. 8, p. 85. Magendie, Leçons, &c. t. 2, p. 91–141. Muller by Baly, Part I. p. 217.

In regard to the termination of arteries, the recent inquiries of Muller, Du Trochet, and others, have fully confirmed, as to all the textures, the statement of Mascagni, that their only termination is in the small veins, and that whatever is evolved or deposited from them in the living body, passes out only by lateral transudation.*

The arteries in the living body (with the exception of the smallest branches, in which a greater variety is observed) are always filled, and even somewhat distended with blood, which is moving towards the capillaries. This blood receives a sudden *increase of velocity* from the impulse of each successive jet of blood from the ventricles of the heart; and from the same cause the arteries are slightly *distended*,—and in many parts of the body even somewhat *displaced*. These effects of the systole of the ventricles constitute what is called the *Pulsation* of the Arteries; but the two last of these effects in the healthy and tranquil state of the circulation, are of small amount, indeed scarcely perceived at any single points; and therefore the pulse in an artery is not distinctly felt, unless the artery is somewhat compressed by the finger, to make the impulse, which its contents receive from the heart, perceptible.

The slight distention which the whole arteries experience, from the impetus of each successive jet of blood from the heart, is sufficient to call into action their elasticity, which enables them to react on the blood, in each interval of the heart's pulsation, and gradually to equalize its motion, until it becomes quite uniform and continuous in the capillaries.

There are many and great obstacles to the free motion of the blood along the arteries,—from the friction of their sides,—from their angular and tortuous course and minute

* Muller, &c. p. 214.

subdivisions,—and from their constant tendency to contraction. The effect of these is not, as some have taught, to make the velocity of the blood in the smaller arteries less than in the larger, but to make its velocity, in all the arteries, less than it otherwise would have been. As we know that no part of the circulating system in the healthy state is continually becoming fuller of blood, we are sure that the quantity of blood delivered into all the veins in a given time from all the arteries, is equal to that received by them from the heart; and this proves, that the velocity of the blood in the capillaries, on the whole, must be less than that in the aorta, just in the same proportion as the area of the aorta is less than the sum of the areas of all the capillaries.

But although this proportion must hold on the whole, yet many facts inform us, that the velocity of the blood, even in vessels of the same size, in different parts of the system, is habitually different; and that the quantity of blood received into, and its velocity in, the smaller arteries and capillaries of all parts of the body, are liable to much temporary variation. Thus, the blood which enters the brain, as it meets with more of the obstacles above mentioned than that which is sent to most other parts, must have an habitually slower motion; the blood which has to make its way against the influence of gravity moves more slowly than other blood in similar vessels, and this especially when the moving powers of the circulation are enfeebled; the velocity of the blood in individual parts of the body is often perceptibly altered by external heat or cold, and by muscular exertion. For these varieties in the flow of blood in different parts, and at different times, there is ample provision in the distensibility of the vessels, and in the possibility of increased velocity in one part compensating for diminished velocity in another,

without the general law above stated being perceptibly violated.

Although the ordinary velocity of the blood in different arteries must be very different, it would appear from the experiments of Poiseuille, that the pressure exerted on the blood in different parts of the body (as measured by the column of mercury which the blood in different arteries will sustain), is almost exactly the same.

In proceeding to form a judgment on the difficult subject of the efficiency of any action of arteries, in causing, or regulating, the movement of the blood, it is first necessary to consider how far the action of the heart extends, and is efficient as a cause of that movement, throughout the vascular system.

It appears from experiments of different physiologists, and especially of Magendie and Poiseuille, that when the circulation of a limb, in a warm-blooded animal, is confined to the branches of a single artery and corresponding vein, the blood stagnates in the vein, whenever the artery is emptied by ligature; but flows freely along the vein, when the ligature on the artery is removed; and that its flow along the vein is varied by any cause that affects its movement in the artery; which shews that any action that goes on in the capillaries and veins of a limb is insufficient to propel the blood, without the impulse *a tergo*, given by the heart, and modified, not increased, by the large arteries. Indeed, a little management gives nearly similar results in a common bloodletting.

Farther, the movement of the blood in all the small vessels of a warm-blooded animal, is always speedily arrested when the heart's action ceases; and although there are various examples on record, in which the human fœtus (always imperfect, however, in other respects), has attained a considerable size without a heart, yet it is doubt-

ful whether any such fœtus has existed which had not been contained in the same womb, and nourished through the same placenta, as another fœtus of the natural structure; in which case the heart of the perfect fœtus would, in all probability, be instrumental in maintaining the circulation of the monster.* It is probable, therefore, that in warm-blooded animals at least, the heart's action is essential to the support of the circulation in every part of the vascular system.

On the other hand, that the pressure of the coats of arteries may act as a powerful cause of motion in the blood, appears from the effects of an opening made in an artery, between two ligatures, and from the rapidity with which the portion of an artery beyond a ligature is emptied of its blood.

In all warm-blooded animals, the action of arteries on their contents seems to be of the same *kind* as that which results from the physical property of elasticity called into action by a distending force; but the following facts appear sufficient to prove that they possess the vital power of Tonicity, as formerly defined, and some degree of that property, which was described as simple Contractility, and these properties must determine a *greater degree* of reaction on their contents, than mere elasticity would occasion.

1. In experiments made by many physiologists, particularly by Verschuir, Thomson, Giulio and Rossi, Parry, Hastings, and Wedemeyer, it appeared, that by various stimuli applied to arteries, chiefly small arteries, which could not affect their mechanical properties, constriction of those arteries, at the points irritated, beginning after

* "Cohæret in *vix non omnibus* talibus monstris funiculus cum placenta infantis gemelli normalis." Elben de Acephalis, &c. p. 116.

the stimulus has been some time applied, lasting some time, and then gradually relaxing, were induced.

2. In experiments made by Hales, and by Wedemeyer, it was found, that when stimulating fluids (such as alcohol or vinegar of a certain strength) are injected into the arteries of newly killed or living animals, there is great difficulty in pushing them forward into the veins; whereas mild fluids in the living body, and these irritating fluids in the dead, pass forward readily.*

3. In experiments made by Mr Hunter, and by Dr Parry, it appeared distinctly that the arteries of dying animals, especially those dying from hæmorrhage, when emptied of their blood, contract immediately after death, and in some instances before death, to a calibre considerably less than that which they afterwards gradually assume, and then maintain till putrefaction begins; which proves, that the tendency of living arteries to contraction is greater than their merely physical properties can occasion.

4. In experiments made by Poiseuille, where an artery from an animal just killed was distended by water urged by the pressure of a given column of mercury, and then the force of its reaction measured by the height of a column of mercury which the water expelled from it could support, it appeared that the force of reaction, excited by the distention of the recent artery, was greater than the force used to distend it; and greater than an artery could exert some time after death, but before any decomposition of its texture had commenced.†

These facts leave no room for doubt that arteries possess, and must occasionally, if not habitually, exert on

* See Statical Essays, ii. p. 124, Edinburgh Medical and Surgical Journal, vol. xxxii. p. 10.

† Magendie, Journal de Physiologie, t. 8.

their contents a truly vital power of contraction, partly of that kind to which the term Tonicity has been strictly applied, partly of that which we have designated as simple Contractibility on a stimulus, but essentially different from Irritability, as formerly defined.*

This being ascertained, we next observe, that various facts shew the course of the blood to be variously modified, and probably much promoted on the whole, by causes acting at a distance from the heart;—in modes which the merely physical properties of arteries cannot possibly explain. The most instructive of these facts are the following:—

1. The great amount of the obstacles which oppose the free flow of the blood into and through the small capillaries of the system; and the force therefore found requisite in the dead body to imitate the flow of blood by injection, especially when injection is attempted in an animal just killed, when the vital power remains in the bloodvessels.

2. The small amount of force found sufficient to stop the flow of blood along the chief artery of a limb, when compared with those obstacles, which the blood moving along that artery must encounter in its passage through the smaller vessels.†

3. The *immediate* diminution produced in the flow of

* The objections stated by Magendie, and by Muller, to this conclusion, are chiefly directed against the untenable theory of Irritability, resembling that of the heart, existing in arteries. Muller admits the vital power of Tonicity in Arteries, and the negative facts stated by him in opposition to the belief of their contracting on stimuli, do not entitle us to set aside the positive facts above stated, as establishing that principle. See Baly's Translation, Part i. p. 202, *et seq.*

† Sir Charles Bell, Essay on the Powers that move the Blood.

blood through the arteries of a limb, by some attacks of palsy, in which the heart's action is unaffected.

4. The greatly increased determination of blood to various organs at particular times, without corresponding alteration of the heart's action, *e.g.* in many cases of partial inflammation of hæmorrhages,—in the case of blushing, and other effects of mental emotion,—in the case of occasional or periodic secretion or nutrition at individual parts, whether natural or morbid, often observed without increase of the heart's action; and contrasting strongly with other instances, where, from mental emotion, exercise, febrile disease, &c. the heart's action is strongly excited, while secretion and nutrition are every where diminished.

5. The alteration which is gradually produced on the arteries of any part of the body, when any cause is applied, which greatly and permanently augments the action going on at *their extremities only;* the influence of which cause is manifestly *retrograde* along the vessels,—*e.g.* the increased size given to the anastomosing branches of a limb, of which the principal artery has been tied,—when contrasted with the shrunk condition of all the arteries of the stump of a limb which has been amputated; —the increased size and tortuous course of the arteries of the uterus during gestation, certainly dependent on the vital actions of the ovum, because taking place at parts quite distinct from the uterus in the case of extra uterine conception;—the increased vascularity of the stomach and intestines during digestion;—the increased size of the arteries of any part of the body, where the growth of a tumour has been excited;* and again the deficient circulation in, and imperfect nourishment of, a

* Sir Charles Bell, *loco citato*.

limb of which the sensitive nerves are palsied, or which is long kept completely at rest (as by disease of a joint) without palsy.

These facts shew, that the flow of blood in the arteries, and especially in the capillaries, of different parts, is in a great measure determined by causes acting at the extremities of the circulation, and bears no fixed relation to the state of the heart's action, being often irregularly distributed, and subject to many local determinations, in health and disease.

But having ascertained the two facts, that a peculiar vital power exists in arteries, and that the distribution of the blood is much affected by causes acting at the extremities of the arteries, we must next state that we meet with extreme difficulties in attempting to explain the phenomena of the motion of the blood through the arteries and capillaries, on the supposition that the only moving powers peculiar to life, are the impulse from the heart, and the pressure of the arterial coats.

The nature of the only contractile power which experiments authorize us to ascribe to arteries is such, that any *increase* of its agency can only be conceived to impede and retard the flow of blood through them, particularly if it be exerted, on the whole, more in the smaller than the larger vessels; and accordingly, in the experiments of Hales and Wedemeyer, it appeared distinctly that this *retarding* effect was produced by injecting such stimulating liquids as must have excited the contractile power of the arteries.

Hence it has been supposed (particularly by Magendie and Mayo) that all local determinations of blood are produced simply by a *relaxation* of arteries, and diminution of their pressure on the blood. And in several experiments made lately in Edinburgh on the con-

tractile power of arteries leading to inflamed parts, as compared with those leading to sound parts, at different periods of the inflammation, and in different parts of their course, this relaxation, or diminution of contractile power (giving, of course, increased effect to the impulse from the heart), was the only alteration that could be perceived to explain the greatly increased determination of blood consequent on the inflammation.*

But if we suppose this relaxation of arteries to be, not merely the accompaniment, but the sole cause, of such determinations, the following difficulties immediately present themselves.

1. If this be so, the only vital power concerned in moving the blood along the arteries is the impulse from the heart; and the action of the arteries, in the natural state, instead of being an auxiliary to overcome the obstacles to the motion of the blood mentioned above, is a great additional obstacle,—so great, that whenever it is lessened in any part of the body, the blood makes its way into that part in very unusual quantity. Now, the amount of those obstacles, and particularly the very moderate impetus with which the blood flows along the larger vessels (as shewn by the facility with which Sir C. BELL and others have found that its flow there can be arrested), strongly impress us with the belief, that, in the natural state, there must be some vital power concerned in *aiding*, not *opposing*, the impulse from the heart.

2. If the cause of all local determinations of blood be merely a relaxation of the arterial coats, then all irritations, healthy and morbid, applied at the extremities of arteries, which certainly excite such determinations, must act as *sedatives* on the contractile power of the arteries;

* Fourth Report of British Association, &c. p. 674.

which is not only the reverse of their action on more strictly irritable textures, but is the reverse of the effect which they have been often observed, in experiments, to produce and keep up, for a considerable time, on individual living arteries, to which they have been applied.

3. The explanation of the phenomena of such local determinations, given by this relaxation of the arteries, must in all cases be incomplete; because in different cases of the kind very different vital changes in the parts effected result,—in one, simple blushing or vascular congestion; in another, increase of secretion or nutrition; in another, serous effusion, without change of the solid textures; in another, inflammatory effusion, with great condensation of the solids; and in another, rapid purulent effusion; and the same principle of simple arterial relaxation cannot embrace all these different changes.

4. In the case of Inflammation, we are certain that this principle is inadequate to the explanation, even of the changes in the motion of the blood along the vessels; because we know that there is in that case retarded movement or absolute stagnation in the vessels most affected, combined with accelerated movement and greatly increased transmission in the neighbouring vessels; and it is impossible to ascribe these two opposite changes in the movement of the blood to the same relaxation of the arterial coats.

Reflection on these difficulties naturally leads us to suspect that there must be some other, and more truly auxiliary cause, influencing the flow of blood in the small vessels, besides the impulse from the heart and contraction of the arteries. And this suspicion becomes much stronger when it is remembered, that a circulation of fluids is carried on throughout the whole vegetable kingdom, and in the lowest animals (as already observed), without any

perceptible aid from the contractions of solids; and certainly without any such peculiarity of structure as can explain the determinate direction of the movement; that even in the lower of the animals that are provided with circulating vessels, a part of the circulation is still of the *diffused* kind, and apparently not referable to the contractions of these vessels; and that in the commencement of existence of all animals, most of the organs acquire a determinate form before the blood exists, or the heart or any contractile part has begun to beat.

Accordingly, Tiedemann, Muller, Burdach, and others, have been led by such facts to acquiesce in the conclusion that local determinations to certain parts of the body, "turgescence or turgor vitalis," are to be ascribed to "a mutual vital attraction or affinity between the blood and the tissues of the body." *

Farther, the following facts, ascertained by microscopical observation of the blood in the capillary vessels of vertebrated animals seem pretty clearly to indicate, as Haller long ago taught, the habitual operation in this part of the animal economy of vital attractions and repulsions, distinct from any contractions of living solids. Their dependence on this principle is not indeed admitted either by Magendie or Muller, but it may at least be asserted that no satisfactory explanation of them on simply physical principles has been given.

1. The smallest arteries, wherever they are distinctly seen, appear quite motionless under the microscope, and the blood runs through them "as through tubes of glass,"—(Haller); in many cases moving in tracks or

* Baly's Muller, p. 224. Burdach Traite de Physiologie, par 774. Fourdan, § 759–762, &c.

lines which have no perceptible coverings, and which are frequently changing.

2. According to Guillot, within a short time after the blood, in such minute vessels, has come to a stand in an amputated limb, its motion may be restored by the application of heat, and go on for ten or fifteen minutes regularly and forcibly.*

3. The *velocity* of the blood in these capillary vessels is subject to great and sudden variations; it is sometimes greater in a part of one of them than in other parts of the same, and often greater in one than in others, or *in the trunk, whence several arise,* which we cannot understand, in vessels the joint area of which increases as they subdivide, if the only cause of motion is an impulse *a tergo*;† and two minute currents may occasionally be seen to meet and unite into a single stream, at right angles to their former course, without retardation of their velocity, which appears also inexplicable on that supposition.

4. The *direction* of the blood in these vessels is also very liable to variation, especially after the influence of the heart on the part inspected has been in any way cut off; and it often exhibits irregularities not explicable by any conceivable changes in the pressure of the larger trunks.‡

It has been so confidently stated by Poiseuille and Magendie that these phenomena as to the varying velocity and direction of the blood in the small vessels, are to be ascribed merely to the existence of an "immoveable lay-

* Journal de Physiologie, t. xi. p. 170.

† Haller, Mem. sur le Mouvement du Sang, p. 56; and Exp. 62, 68, 72, 93, 262, &c. Dollinger, in Journal des Progrès, t. ix. p. 8. Wilson Philip on Sleep and Death, p. 71.

‡ Haller, Mem., &c. p. 90; and Exp. 54, 93, 228, &c. Marshall Hall on the Circulation, p. 87. Kaltenbrunner, Exp. circa Statum Sang. in Inflamm. p. 5.

er" of the *liquor sanguinis* adhering to the sides of the vessels, in which many of the globules are occasionally fixed or entangled, that we cannot at present lay much stress on these observations. But it seems very doubtful whether the presence of this immoveable layer affords a satisfactory explanation of all those varieties in these respects which have been often and distinctly observed.*

5. Long-continued and regular *oscillations* of the globules of the blood in the minute vessels are often observed, particularly in animals with languid circulation, or after death; and when these are seen, as they have often been, in capillaries, while there is no motion in the larger vessels supplying them, or in lines of globules that have no communication with larger vessels, and extending only to a part of these lines of globules, it appears certain that no contractions of vessels are concerned in producing them.†

The explanation of these oscillations, given by Poiseuille and Magendie,‡ who ascribe them to the alternate agency of the mechanical actions of the heart, and the elasticity of the vessels, is no doubt strictly applicable to many such movements; but it is certainly not applicable to those regular and long continued oscillations distinctly observed by Haller, Kaltenbrunner, and others, *(locis citatis) after the heart was at rest, or had been cut out of the body.*

6. The *derivation* of the blood, in all directions, towards a wounded vessel—certainly independent of the heart's action, because most remarkably observed after

* See Magendie, Leçons sur les Phénomenes Physiques de la Vie, t. 3. p. 259 *et seq.*, and 343 *et seq.*

† Haller, Mem. &c. p. 88; and Exp. 225, 229, &c. Kaltenbrunner in Journal de Physiol. t. viii. p. 83–89. Dollinger in Journal des Progrès, t. ix. p. 22, *et seq.*

‡ Magendie, Leçons, p. 32, &c., t. 2, p. 343, and t. 3, p. 272, 275.

the heart has been cut out of the body—appears also to take place in circumstances where it must be independent of contractions of vessels, if Haller's statement is correct, that it may be seen in vessels which do not appear filled with blood, and *which do not contract during it*, and has the effect of gradually filling vessels which had become empty, and of resolving coagula which had begun to form.*

7. Globules of blood that have escaped from vessels and been effused on membranes, have been observed to follow one another in determinate directions, even against the influence of gravity, for some time.†

8. When lymph has been effused from injured or inflamed vessels, files of globules of blood slowly and gradually make their way through it, and the tracks which they follow become capillary vessels, not as if forced by a *vis a tergo*, but nearly in the same way as the first globules of the blood arrange themselves on the germinal membrane of the chick in ovo, in the commencement of its life, where the formation of various parts is distinctly in progress before the heart acts, or any contractile vessels are formed.‡

Although it be granted that several of these observations may have been fallacious, there will remain enough uncontested nearly to establish a proposition which is so strongly supported by the analogy of some of the lower animals, and of vegetables; and the application of which

* Haller, Mem. &c. Exp. 179, 180, 182, 183, 224, 225, and p. 336. Andral. Precis d'Anat. Pathol. t. i. p. 27.

† Haller, Mem. &c. Exp. 208, 214–16, 225, &c. Kaltenbrunner, Exp. &c. p. 66, 85.

‡ Haller, Mem., &c. Exp. 180. Kaltenbrunner, Exp., &c. p. 22, *et seq.* Gendrin, Hist. des Inflammations, § 1566, *et seq.* Royer Collard, Essai d'une Systeme de Zoonomie, p. 80.

to the difficulty above stated, as to the local determinations of blood in the higher animals, is so obvious and satisfactory.

The contracted condition of the arteries of a stump, or of the main artery of a limb which has been tied, *above* the ligature, when contrasted with the distended state of the collateral branches in the latter case, has been already stated as a certain fact, which seems inexplicable, if the blood, at any part of the arteries, is supposed to be moved only by a *vis a tergo*. And the microscopical observations of Haller, and Kaltenbrunner, on the manner in which the blood deserts the branch of a vessel, so obstructed—*licet lumine hiet aperto*—and passes into anastomosing branches, seem clearly to indicate the efficacy of some attracting power, modifying the effect of the *vis a tergo*.*

Farther, the existence of an attracting power among certain of the particles of the blood, and its importance in maintaining the capillary circulation, seem to be strongly confirmed by the important fact, lately ascertained by Magendie, that when the fibrin or coagulating part of the blood is partially abstracted, or when its coagulating property is suspended by the admixture of carbonate of soda, the blood can no longer be retained in the capillary vessels, and extravasations of it occur at various parts, and especially in the lungs, very similar to those observed in various diseases where the blood loses its power of coagulation.

It appears from his experiments that when the blood loses its power of coagulating, extravasation and obstruction infallibly occur ; " La moindre modification apportée dans la faculté qu'a le sang de se coaguler entraine des troubles

* Haller, Mem., &c. Exp. 54. Kaltenbrunner, l. c. § 20, 21. See also observations by Reichel to the same purpose, quoted by Burdach, Physiol. § 764. 2.

immediats." "Le sang par cela seul qu'il ne peut plus se prendre en masse, cesse de respecter la barriere que lui opposent les parois de ses tuyaux, pour s'epancher dans les tissus voisins."—*Ib. t.* iii. *p.* 7.

Now, that peculiar condition of the blood during life, which is thus essential to its circulation in the capillaries, will afterwards appear to be strictly a vital phenomenon—probably dependent on peculiar attractions and repulsions among its particles. This is partly admitted in the following statement of Magendie himself. "La cause de la formation de caillot doit etre cherchée dans l'absence du contact entre le liquide et les parois de ses tuyaux. Quelle est donc cette harmonie si parfaite dont le derangement entraine de si graves consequences?" "Je l'ignore. *Elle dure avec la vie, et s'eteint avec elle.*"—*Ib. t.* 2, *p.* 257.

That the peculiar chemical changes, which are wrought on the blood in all parts of the body, should be, to a certain degree, a cause of its movement, is only what might be expected from facts ascertained by Reuss, Du Trochet, and others, as to motions produced in inanimate fluids by their chemical and electrical relations. And that the chemical changes on the blood at the lungs, or its reception of oxygen there, are really a powerful auxiliary cause of its motion through the lungs, will appear distinctly from the facts to be stated as to death by Asphyxia.

In so far as the movements of fluids through living bodies are determined by the chemical changes which they there undergo, they may be supposed to bear the same relation to the vital affinities, by which those changes are effected, as the phenomena of Endosmose and Exosmose bear to ordinary chemical attractions. But the principle expressed by these words, cannot be admitted as affording a more direct explanation of any movement,

or changes of movement, in the living body, which are so strictly vital, and so liable to be affected by causes which cannot affect dead matter (*e.g.* by mental acts or feelings), as those auxiliary powers certainly are, which influence the flow of blood in the capillaries. As the vital affinities obviously act with greater energy in individual parts of the body, at some times than at others (*e.g.* at the lungs during inspiration, at the stomach during digestion, or at the uterus during gestation), we can understand how local determinations of blood should be produced (by attraction rather than propulsion) by causes exciting the vital actions at the ends of the arteries. The increase of nutrition, secretion, or excretion, is in such cases, at least in the first instance, the cause, not the effect, of the increased flow of blood to the parts concerned; just as the excitement of vital action in a branch of a tree exclusively exposed to the sun is the cause, not the effect, of an exclusively increased flow of sap into it.

But some of the microscopical phenomena above noticed (as the oscillations, the derivation of blood to wounded vessels, the adhesion of portions of blood to one another, &c.) seem to be unconnected with any chemical changes; and these have been ascribed, with some probability, to the existence, in the particles of the blood, of a certain degree of the same attractions and repulsions, and the same liability to the action of stimuli, as are found in the particles of the same matter constituting muscular fibres.

It is to be remembered, however, that although the powers of which we have now treated, appear to be of great efficacy in promoting the flow, and regulating the distribution of the blood in the capillaries, and therefore of great importance in Pathology, yet the experiments of Magendie and of Poiseuille (already quoted) shew that,

in the healthy state, they are inadequate to the propulsion of masses of blood along the larger veins.

The Veins into which the blood is delivered by the small arteries and capillaries, become gradually, though not uniformly, larger when traced towards the heart, and terminate ultimately in the venæ cavæ and coronary vein. Those which are of sufficient size to be examined, are found to consist only of two coats, corresponding to the outermost and innermost of the coats of arteries, but possessed of greater strength. Hence they are thinner and less elastic, but more distensible and tougher, than the arteries. Near the heart, and in various other parts of the larger veins, thin irregular layers of fibres, more or less resembling those of muscles, are interposed between their coats.

The veins in the extremities, and generally in muscular parts of the body, are provided with valves, constructed nearly in the same manner as those at the mouth of the aorta, with their free edges towards the heart.

There are two important singularities in the venous system; *first*, The Sinuses within the cranium, formed by separation of the laminæ of the Dura Mater, into which the veins of the Pia Mater open obliquely in a direction opposite to the current of the blood, the effect of which is to lessen the effect on the vessels of the brain, of any stagnation and congestion of blood in the great veins near the heart; *secondly*, The distribution of the Vena Portæ, (which is of great size and strength, and collects the blood from the stomach, intestines, pancreas, and spleen), through the substance of the liver, after the manner of an artery. In many of the lower animals, the venous blood from the lower extremities is, in like manner, diffused through the kidneys.*

* Jacobson, Edin. Med. Journ. vol. xix.

Besides being more distensible, the veins are considerably more numerous and more capacious than the arteries, and their larger branches anastomose much more freely. Hence the quantity of blood in the veins is always much greater, and is liable to greater variations, both locally and generally, than that in the arteries.

From the smaller capacity of the arteries, and from the pretty uniform distention, on the whole, of all parts of the vascular system, it follows, that the velocity of the blood in the veins must, on the whole, and in the same proportion, be less than that in the arteries. And from the sum of the smallest veins of the body having a much larger capacity than the venæ cavæ, it follows, that the velocity of the blood in these smallest veins must, on the whole, and in the same proportion, be less than that in the venæ cavæ. But the circumstances stated as to the structure of veins, admit of greater local and temporary variations of the velocity of the blood in them, without perceptible deviation from these general laws, than can occur in the case of the arteries. Absolute stagnation, and even retrograde movement, for a time, of blood in individual veins, have often been observed in experiments on animals.

The ordinary motion of the blood in the veins is continuous, with these exceptions, *first,* That, in a state of great weakness, when the arteries are very little distended by the stroke of the heart, the blood in the smallest of the veins retains somewhat of the intermitting motion; *secondly,* That the flow of blood in the great veins, even independently of disease, is slightly retarded at each systole of the auricles, and accelerated on their diastole; *thirdly,* That the flow of blood in the great veins is somewhat retarded by each act of expiration, and accelerated by each inspiration ; the natural effect of the enlarge-

ment of the shut cavity of the chest, in inspiration, being to draw towards it, (*i. e.* to cause the pressure of the atmosphere to urge towards it), not only air by the trachea, but also blood by the great veins. This last is the Respiratory Pulse of Haller and others, which is distinctly seen to communicate a movement to the brain and spinal cord, when they are exposed.

The motion of the blood in the veins is manifestly determined by various causes.

1. Probably the most efficacious is the impulse *a tergo* communicated by the heart and arteries, the effect of which is unequivocally shewn by the experiments mentioned at page 56. But when we consider the great distensibility of the veins, and the very moderate degree of distention observed in them in the healthy state, we cannot doubt, that the motion of the blood along them must be much aided by causes acting in this part of the circulation itself.

2. The experiments of several physiologists, particularly Verschuir, Hastings, and Beclard, seem sufficiently to indicate a vital power of Tonicity, and even of Contractility on irritation in the veins, similar to that which we ascribed to the arteries. But in several parts of the body, as in the interior of bones, and in the substance of the liver, where the coats of the veins form the internal lining of unyielding canals, it is obvious that this power cannot be exerted ; and in any individual part it is probably a feeble power.

3. Gravitation manifestly affects the flow of blood in the veins, especially of the extremities ; but cannot materially, on the whole, promote the flow towards the heart.

4. The action of neighbouring muscles, and probably the pressure of other adjacent and especially elastic textures, such as the skin, aided by the effect of the valves,

frequently and greatly promote the flow of blood in many veins, chiefly of the extremities.

5. It appears that the "suction influence" of the diastole of the auricles of the heart, promotes the flow of blood along the veins somewhat more than their systole retards it.* But the rapid distention of a vein below a ligature, where this cause cannot act, shews that the other causes of the motion in the veins are much more powerful.

6. It appears from the experiments of Sir David Barry, confirmed by those of Poiseuille, that the motion of the blood along the veins is promoted also, in animals of which the respiration is similar to the human, by the "suction influence" of the acts of inspiration above mentioned. But, besides what was observed in the last paragraph, the facility with which circulation is carried on in the fœtus, which does not breathe; in animals, of which the pericardium has been opened, and the heart exposed to the air (so that no influence of this kind can affect the motion of the blood); and even in cases of artificial respiration, where no such influence can be exerted by the chest—sufficiently demonstrates that this cause likewise is of comparatively inconsiderable amount.

7. The Vital Attractions and Repulsions, which we consider as taking place in the capillaries, are likewise pretty certainly, a cause of movement in the veins, as will appear more distinctly when the effects of the changes on the blood at the lungs come under our view.

The effect of the more violent respiratory actions on the flow of blood in the veins, and particularly the retardation of the blood's motion, and congestion in the

* See particularly Wedemeyer in Edin. Med. and Surg. Journal, vol. xxxiv. p. 89, and other observers, quoted by Burdach, Physiol. § 722. ii.

great veins, from forced or prolonged expiration, accompanied by muscular effort, are very important in Pathology. Muscular exertion, especially of the respiratory muscles, has the additional effect of accelerating the flow of blood in the arteries, which will be considered afterwards.

The Pulmonary Artery and its branches are similar to the other arteries of the body, and the pulmonary veins to other internal veins. The termination of the smallest branches of the artery in the capillary veins of the lungs, has been ascertained as distinctly, and in the same manner, as in other textures; and the smallest branches of the bronchial arteries, which bring arterial blood from the aorta, have been found to inosculate with those of the pulmonary artery.

As the whole of the pulmonary circulation is carried on within the cavity of the chest, it cannot derive any aid, on the principle of suction, from the movements of the chest. But the motion of the lungs in inspiration and expiration promotes the flow of blood through their substance, for reasons which will appear afterwards.

The fibrous middle coat found in the pulmonary artery and its branches, as well as in the aorta, is probably chiefly useful by resisting the strong and variable impulse given by the heart's contractions, and thus preventing morbid dilatation of the arteries. And it is with the same intention, no doubt, that the great veins are strengthened by muscular fibres near their termination, where they are exposed to the retrograde impulse from the stroke of the auricles.

The whole quantity of blood in the body has been variously estimated at from 1-5th to 1-8th of the weight of the whole body, and of this, it is generally thought that about 1-4th may be in the arterial, and 3-4ths in the venous system.*

* See Burdach's Physiol. § 691.

CHAPTER V.

OF THE COMPOSITION AND PROPERTIES OF THE BLOOD.

This subject demands careful attention before we can proceed to state the uses of the Circulation.

The Blood in the living body, or immediately on emission from the vessels, consists of a clear fluid, in which a very great number of red particles are suspended. Its specific gravity is about 1050, and its temperature about 98°. Within a few minutes after emission, in the natural state, it divides itself into a yellowish fluid called *Serum*, and a dark red spongy mass called *Crassamentum.*

In some cases, chiefly morbid, the crassamentum is spontaneously divided into two parts, the *colouring matter*, which lies lowest, and a whitish tenacious substance called *Fibrin*, which covers its surface. And in all cases, this division of the crassamentum into two parts may be accomplished, either by carefully stirring fresh drawn blood with a stick, to which nearly all the fibrin, and little of the colouring matter, adheres; or more completely, by repeated affusions of cold water and pressure, by which the colouring matter is carried off and the fibrin left.

Of the three substances into which the blood is thus divided, it has been generally believed in this country that the Serum and Fibrin are combined *in the clear fluid* of the living blood, and that coagulation depends on their separation, on the fibrin taking the solid form, and the red globules attaching themselves more or less completely to it.

That this is the true account of the matter (although opposed to the statements of Prevost and Dumas, Denis, and others, who think the whole fibrin is contained in the globules of the living blood) appears clearly from the following facts.

1. Haller* and others have observed, that in cold-blooded animals, wounds of the small bloodvessels may be seen, under the microscope, to be closed up by a gelatinous matter, which separates from the fluid part of the blood, and is obviously distinct from the globules.

2. Muller has found that the globules of the blood just drawn from cold-blooded animals, may be caught on a fine filter unchanged; and that the fluid which passes through the filter subsequently coagulates.†

3. When the mixture of serum and colouring matter, which is left after the fibrin of fresh drawn blood has been removed by agitation, is examined with the microscope, it is not difficult to perceive (although Berzelius made a different statement) that the colouring matter retains the form of globules, such as are seen in the fresh drawn blood before it has coagulated, and these may be seen to undergo the same changes as the fresh globules when mixed with water under the microscope; they swell out into a globular form, and first their colouring matter is dissolved away, and then (if the blood examined is that of warm-blooded animals) the colourless bodies gradually disappear.‡ It is plain from these facts, that the Fibrin is dissolved in, or incorporated with, the serum in the living body,—that coagulation depends on its assuming the solid form,—and that in this process the globules are passive.

* Exp. sur le Mouvement du Sang, Ex. 157, 176, &c. p. 302. Also, Gendrin, Hist. du Inflam. § 1441, 1480, *et seq.*

† Baly's Muller, p 111.

‡ Ibid. p. 113.

In the clear fluid of the blood, or *liquor sanguinis*, before its separation into serum and fibrin, other globules, smaller, more spherical, and of less polished surface, have been observed, by Hewson, Muller, and others, which are very probably the rudiments of the more perfect globules.

This peculiar constitution of the blood,—a clear fluid, in which many globules are suspended, and of which, besides, a portion becomes solid when it is drawn from the living body,—is found in the nourishing fluid of almost all animals, and of many vegetables, and the principle which gives fluidity to the coagulable portion while it circulates in the living body, is evidently of primary importance in physiology.

When we state the chemical composition and properties of the constituents of the blood, or of any other animal substance, two cautions must always be kept in mind.

1. The proximate principles which are procured from these substances, have not necessarily existed in them just in the form in which they appear, but may be in part the products of the chemical operations, however simple, by which they are shewn.

2. As we know that the peculiar combinations of Carbon, Hydrogen, Oxygen, and Azote, which form the animal principles, tend continually to dissolution, and cannot be recomposed by art, we cannot doubt that the chemical affinities of these elements are somehow modified, in those vital actions in which the animal principles are formed; and until we know something of the Laws according to which chemical affinities are controlled and altered in the living body, we cannot expect that the chemical examination of dead animal matter will give much assistance to Physiology.

The following are the most important results of such

chemical examination of the three substances into which fresh drawn blood divides itself, as may be supposed to make little change on the condition in which they existed in the living body.

1. The Serum has a specific gravity of from 1027 to 1030. When it is heated to 160°, an abundant coagulum of *Albumen* is formed in it, similar to that which is formed in the same way from the glaire of the egg. This coagulated albumen once formed from either fluid, is insoluble in water,—soluble, by the aid of heat, in the caustic mineral alkalis,—is formed into a substance resembling gelatin by the long-continued action of acetous acid, or diluted nitric acid,—and is little prone to putrefaction.

The fluid which drains or may be expressed from coagulated serum is called the Serosity. It consists of water holding in solution a little of an uncoagulable animal matter, which has been called Muco-extractive; which shews itself on evaporation, is soluble both in water and alcohol, and may be precipitated by acetate of lead; and also a little of the following salts,—Soda or its Sub-carbonate, Muriate of Soda, Sulphate, and Muriate of Potass, and Phosphates of Lime, Magnesia and Iron.

A fixed oil is often suspended in the serum, in such quantity as to give it a somewhat milky appearance, and in smaller quantity is now known to exist always in it. It is most easily shewn by agitating the serum with æther, which dissolves it, and then allowing the æther to evaporate; and it spontaneously separates into two parts, one a fatty matter, which has been likened to the substance of the brain, the other a fluid oil. This fatty matter is also in part attached to the fibrin of the blood. Parts of it have been stated to possess the properties of the cholesterine, and of the colouring matter of the bile, and

facts to be afterwards stated, make it highly probable, that these materials of the bile always exist, in minute quantity, in the blood.*

The proportions of these different ingredients in the serum are,

According to Marcet,

Water,	900
Albumen,	87
Muco-extractive,	4
Salts,	9
	1000

According to Le Canu (who separated the oil from the albumen),

Water,	901
Albumen,	81.2
Animal matter soluble in Water,	4.6
Animal Oil,	3.4
Salts, and loss,	9.8
	1000

2. The *Fibrin* has a peculiar tendency to assume the fibrous form. In chemical relations it differs very little from coagulated albumen.† Both are resolvable, as the products obtained from them by the full action of heat shew, into Carbon, Hydrogen, Oxygen, and Azote, and the chief difference between them lies in the fibrin containing rather less oxygen and more azote. The proportions have been thus stated,

	Carbon.	Hydrogen.	Oyygen.	Azote.
Albumen,	52.8	7.5	22.8	15.7
Or,	17	13	6	2 atoms.
Fibrin,	52.8	7.0	19.6	19.9
Or,	18	14	5	3 atoms.

* Beudant in Arch. de Medecine. January 1838.

† Hatchett, Phil. Trans. 1800. Berzelius, View of Animal Chemistry.

3. The colouring matter is quite insoluble in the serum, but readily unites with water, as is shewn by the means of separating it from the fibrin. The solution, or intimate mixture, of this matter in water, is acted on by heat nearly as serum is ; and the solid matter deposited from it does not appear to differ materially from coagulated albumen, except in colour, and in yielding a small quantity of oxide of iron, not only when burnt, but, after the application of chlorine, by its liquid tests. The colourless nuclei which may be separated from the colouring matter of the blood of the frog by the solution of the latter in water, have the properties of coagulated albumen. In the blood of the mammalia, although such nuclei probably exist, they cannot be distinguished from the soluble portion of the globules.*

4. Carbonic acid is usually disengaged from fresh drawn blood, but in variable, and generally very minute quantity ; in some cases it is not obtained, even by the action of the air-pump ; but experiments, to be afterwards described under the head of Respiration, seem sufficiently to demonstrate, that both this acid and free oxygen always exist in blood, probably uniformly diffused, like the saline matter, through its substance.

The colouring matter, although it cannot maintain the solid form, without the assistance of fibrin as a cementing medium, and although it is probably impossible to separate it completely from the other constituents of the blood, constitutes the greater part, and the densest part, of the crassamentum ;—its quantity is certainly more than ten times that of the fibrin, in a portion of crassamentum properly dried ; and its specific gravity 1126 or 1130, that of the whole crassamentum being 1077 or 1084.†

* Baly's Muller, pp. 104 and 120.

† Davy, De Sanguine. Edin. 1814.

In order to ascertain the comparative quantities of the solid matter of the serum, and solid matter of the crassamentum, in blood, it is necessary to evaporate slowly to perfect dryness a given weight, first of the serum, and then of the crassamentum, and weigh the residuum in each case; and then to allow as much of the residuum, in the second experiment, to be solid matter of the serum, which had been contained in the crassamentum, as the result of the first experiment shews to be the proportion in the pure serum, corresponding to the quantity of water that has been driven off. The remainder of the last residuum only, is the weight of the solid matter of the crassamentum itself. It is important to attend to these proportions, because they appear to be liable to much variation in disease. The average results of trials made in this way by different experimenters, shew that of the whole blood more than one-fifth is solid matter, and that of the solid matter nearly three-fifths are in the crassamentum.

The proportion of the solid matter of the crassamentum in the blood is found to vary remarkably, according to the quantity drawn, when that is considerable,—being much less in the last drawn blood than in the first; probably because the evacuation causes the return into the larger vessels of much of the thinner part of the blood, previously diverging into the smallest capillaries.

The proportions of the solid matter of the crassamentum and of that of the serum, to the whole blood, appear also from the inquiries of Le Canu and Denis, to be very various in different individuals, the former in particular being greater in sanguine and robust than in phlegmatic and weakly persons; and greater in men than women; and a similar difference is observed between the more active and more torpid states of animals, insomuch that

in frogs the blood sometimes does not coagulate during winter.*

The average proportions, as ascertained by Prevost and Dumas, in human blood, and the variation in different circumstances, are shewn in the following table :—

	Water.	Solids of Crass.	Solids of Serum.
Average, ...	783.9	129.2	86.9
In women (10 experiments by Le Canu), ...	804.3	115.9	79.6
In patients with inflammations (8 trials by Dr Whiteley),†	713	182	104

The quantity of the Fibrin contained in blood is also liable to much variety; when thoroughly dried its average has been stated at less than 1 part in 1000, but the numerous experiments of Le Canu give an average of 4.3 in 1000 parts of blood.‡

The Globules of the blood in the living body, possess very singular properties. They contain the whole colouring matter, though in varying proportion. They have, in every species of animal where they exist, a determinate form, circular and flattened in man, as in all the Mammalia, oval in all the other vertebrated animals. Their size appears from the numerous and careful observations of Muller to be less uniform than has been represented, but seldom to vary more than from $\frac{1}{3000}$ to $\frac{1}{4000}$ of an inch in diameter in man; when in motion in the living and healthy body they never coalesce. They have such tenacity as to regain their form and size after being

* Muller, Ann. des Sciences Nat. t. xxvii.

† De Sanguine; Edin. 1832. The greater density of the blood in inflammatory diseases, is probably chiefly to be ascribed to the opposite cause from that assigned for the attenuated state of the last drawn blood of a single bleeding. When the circulation is morbidly vigorous, less than usual of the more serous parts of the blood returns to the large veins from the capillaries.

‡ Journal de Pharmacie, 831.

compressed and flattened, as they sometimes are in narrow bloodvessels; and when at rest tend to arrange themselves in somewhat determinate forms.* But these properties they seem gradually to lose after they are removed from the living body.

Several observers have thought that when removed from the body, especially if floating in serum, they shew spontaneous motions which may be regarded as vital; but it seems now generally agreed that these movements are of too irregular a kind, and last too long after they have been withdrawn from a living body, to be of this description, and that they depend only on mechanical causes, chiefly currents in the liquid containing them, and its evaporation.

So many of the animal principles which exist in the solids and prepared fluids of the body have now been detected in the blood, that physiologists naturally incline to the opinion, that this fluid is much more complex than it has often been thought, and contains in it "the whole organization of the body in the liquid form."† On the other hand, it has been recently maintained by Schultze, that the blood truly consists only of two substances, the plasma, or liquor sanguinis, and the vesicular matter or globules. But, although it is probable that every particle of the liquor sanguinis contains a minute portion of all the constituents which compose it (in like manner as any particle of organized matter contains a minute portion of salts), yet there are various facts to be stated afterwards,—besides the facility with which various matters (Fibrin, Albumen, Oil, Extractive Matter, Salts, sometimes Urea) may be made to appear in that fluid,—

* Prevost and Dumas, Annales des Sciences Naturelles, t. 12.

† Burdach.

which strongly support the opinion, that different compounds exist in it ready formed, requiring only to be attracted out of it, not to be actually elaborated, in the different organs of the body.

The phenomena of the Coagulation of blood demand consideration, chiefly as being an indication of truly vital properties, now pretty generally admitted as existing in the blood during its connection with the living body, and the alteration of which must evidently constitute an essential part of any satisfactory system of Pathology. This change generally begins in two minutes, and extends to the whole mass in six or seven, after blood is drawn, but cohesion of the coagulum formed continues to increase often for many hours after. It consists in the fibrin becoming concrete, and assuming a filamentous reticular form,—in the interstices of which the globules are lodged,—and then gradually contracting; and as the fibrin is of somewhat less specific gravity than the colouring matter, the coagulum appears first, and is firmest, at the upper part.

The coagulation of blood is not attended with any decided elevation of temperature, nor is it necessarily, although frequently, attended by any evolution of carbonic acid. It is promoted by heat (up to 120° of Fahrenheit), by exposure to air, and by rest or gentle agitation only, but is not prevented by the opposites of these. It takes place very slowly, even when blood is at rest, in the living body. It is accelerated by separation of the particles of blood from one another on a flat surface, even *in vacuo;* and more remarkably by an increase of the serous part of the blood; and this is obviously part of the reason, why blood drawn from the veins of persons weakened by loss of blood, or fainting, or of dying animals,—be-

ing, as already observed, more serous,—coagulates much more rapidly than the blood drawn previously.*

In regard to the cause of the coagulation of blood, and of the varieties observed in that process, we may state that there is now conclusive evidence, 1. That the fluidity of the blood in the living body is a vital phenomenon, and its ordinary coagulation not referable to any chemical or physical principle, but dependent on the loss of vitality; and, 2. That although the fibrin is probably always deposited from the serum when blood is separated from the living body, yet such aggregation and contraction of the fibrin as take place in ordinary coagulation, is a vital process, liable to alteration by causes which affect vital action, but cannot otherwise alter the constitution of the blood. This evidence may be stated thus:—

I. Coagulation cannot be owing merely to Rest, because it cannot be prevented by agitation of the blood out of the body,† (although the coagulum formed, if the agitation be violent and continued, is diffused in minute particles through the fluid); nor can it be owing to Cold, for it is promoted by the temperature of 100°, out of the body; nor to exposure to Air, for it takes place rapidly in vacuo, or in a shut sac in the dead body; nor to escape of Carbonic Acid, for it can take place without perceptible evolution of gas,‡ and is not prevented from taking place when carbonic acid is agitated with and absorbed by the blood;§ and we can see no other physical change attending the emission of blood from the body to which

* Davy, Thesis, 1814. Schræder Van der Kolk, De Sanguine Coagulante, Groningen, 1820.

† Davy, Edin. Med. and Sur. Jour. vol. xxx.

‡ Turner's Chemistry, p. 747. § Davy, *loco citato.*

to ascribe this effect. These facts lead us, therefore, to believe, that the coagulation is the effect of loss of vitality. And this is confirmed by observing, that blood will remain long fluid, although at rest, if inclosed in a living receptacle, especially an artery or vein, and be still capable of coagulation if withdrawn from that receptacle.* Thus, although the last drawn blood from the veins of an animal bled to death may coagulate almost instantly, yet the blood taken, nearly an hour after apparent death, from the large vessels of the same animal, may be found fluid, and coagulate slowly.

II. But if ordinary coagulation were nothing more than the death of the blood, we should never see blood drawn from the body remain apparently fluid, as we often do; and the following facts appear sufficient to confirm the doctrine of Mr Hunter, that the aggregation of the fibrin in coagulation is a truly vital process—a last exercise of its vital powers, somewhat similar to the stiffening of muscles.

1. If this aggregation be prevented by agitation, continued for some hours after blood is withdrawn, the blood has no power to form a firm coagulum afterwards, although its chemical properties remain unchanged until it putrefies.

2. The aggregation of the fibrin of the blood is affected by heat and cold nearly as all vital actions are; it is accelerated by moderate heat, and permanently arrested by long-continued cold (as by freezing blood for thirty-six hours), and also by raising its temperature rapidly to 140° (a heat short of that which coagulates its albumen.) †

* Thackrah on the Blood, ch. v.

† Prater, Experimental Inquiries in Chemical Physiology, p. 12, 13.

3. This process is *prevented* by various causes, which powerfully depress all vital action; as we see in cases of sudden death from concussion, suffocation, mental emotion, muscular exertion, or the most violent poisons, or most rapid diseases, where the blood remains permanently fluid, the whole fibrin being diffused in minute particles through the mass.

4. Coagulation of the blood in individual parts is *produced* in certain circumstances, even of the living body, by causes affecting, but not destroying vitality, and by which the physical properties of the blood must be unaffected; *e. g.* if the parts to which it is going be in a state of gangrene,—or if the vessels containing it have been severely injured, as in contused or lacerated wounds, —or if it be kept *long at rest* in any part, as in an aneurism, or a diseased or obstructed vessel. In such cases the coagulum formed is gradually decolorized, and as the colouring matter, in an aneurismal sac, first disappears from the part of the coagulum which is farthest from the still liquid portions of the blood, we must suppose that it is absorbed in preference to the fibrin.

5. The coagulation of the blood and aggregation of the fibrin are much *altered* in different diseases. In typhoid diseases the aggregation of the coagulum is much diminished, sometimes altogether suspended; and in inflammatory diseases there are several changes; the fibrin and globules have a peculiar tendency to separate from one another; and the fibrin, so separated, forms the buffy coat;*

* This does not depend on the circumstance of slow coagulation of blood, and consequent separation by gravity of the colouring matter from the fibrin, but on an unusual tendency to separation between these substances. Whether this is owing to increased aggregation among the particles of each, or to a peculiar repulsion between the two, is doubtful; but of the existence and the tendency there are two

the aggregation of the fibrin becomes in general unusually great, the proportion of fibrin in the whole blood is gradually increased;* and the albumen appears to attach itself in increased quantity to the fibrin; † and these changes in the blood drawn from the veins correspond perfectly to the changes, seen with the microscope to be gradually effected, in the blood of the inflamed vessels themselves.

All these modifications of the process of coagulation are from causes which powerfully affect vital action, but cannot be supposed to alter materially the physical or chemical properties of the blood; and several of these clearly indicate that the condition of the blood during life is constantly dependent on an influence somehow communicated to it from the living solids surrounding it, and liable to great and sudden change from *impressions* made on these living solids; which is a principle of obvious and great importance both in Physiology and Pathology.

It does not appear possible to conceive a single property in the blood capable of comprehending all the phe-

simple proofs. 1. That the formation of the buffy coat (though no doubt favoured or rendered more complete by slow coagulation) is often obsreved in cases where the coagulation is more rapid than usual; and the colouring matter is usually observed to retire from the surface of the fluid in such cases, before any coagulation has commenced. 2. That the separation of the fibrin from the colouring matter in such cases takes place in films of blood, so thin as not to admit of a stratum of the one being laid above the other;—they separate from each other laterally, and the films acquire a speckled or mottled appearance, equally characteristic of the state of the blood, as the buffy coat itself.‡ These facts, as to the formation of the buffy coat, appear to have been overlooked by Magendie.§

* Scudamore on the Blood, p. 89, *et seq.* Whiteley, De Sanguine; Edinburgh, 1832.

† Gendrin, Op. Cit. § 1419.

‡ Schrœder Van der Kolk. l. c. § Leçons, &c. t. iv.

nomena which are peculiar to its living state. It has been supposed that the principle of attraction or aggregation among the particles of fibrin, on which the coagulation depends, is opposed during life by a principle of repulsion, which acts at shorter distances, and subsists for a shorter time after the blood is drawn; that both are truly vital properties, and that this last principle of Repulsion, or Vital Elasticity, is what keeps the fibrin fluid during life.*

This supposition does not seem more complex than the facts to be included under it require; and the properties thus attributed to the blood are strikingly analogous to those which are indicated by the vital actions of muscular fibres. Accordingly, in cases of the most sudden and violent deaths, the post-mortem contractions of the muscular fibres, as well as the aggregation of the fibrin of the blood, are nearly or entirely prevented; and these processes are somewhat similarly affected by various agents.† Indeed, all the effects produced on the coagulation of blood, by various agents which do not appear to affect its chemical constitution, seem in general to be compatible at least with the supposition that the precipitation of the fibrin depends on the loss of a peculiar vital power of Repulsion, acting only at very short distances, and easily destroyed; and that the subsequent aggregation of the coagulum depends on the predominance for a time of a stronger vital power of attraction.‡

One of these is the effect of dilution with serum (*i. e.* with a weak saline solution) in promoting coagulation.

Although this last fact is obviously one cause why the blood last drawn from a fainting or dying animal, being

* See Prater's Experimental Inquiry, &c. p. 214. *et seq.*

† Ib. § 5. ‡ Ib. § 2, and Magendie Leçons, &c., t. 4.

more serous, coagulates more rapidly than that first drawn, and therefore seldom shews the buffy coat in cases of inflammation, yet the rapid and imperfect coagulation of blood drawn in such circumstances must also be partly ascribed to the shock by which its vitality is affected, nearly as by other causes of concussion or sudden death.*

The idea above stated of the vital properties concerned in the coagulation of the blood, agrees perfectly with this leading fact, that when coagulation is unusually rapid (all the vital power being speedily extinguished) it is also feeble, or the aggregation of the coagulum slight; and when it is slow (the vital properties departing very gradually) it is found to be, *cæteris paribus*, strong, *i. e.* the aggregation of the coagulum firm.

According to these views, it may be supposed that the properties of Irritability and Tonicity in muscles are only an increase and more perfect exemplification of the same vital powers of Attraction and Repulsion which exist in certain of the constituents of the blood; and it may be thought that the property of irritability may resolve itself into the more general principle of Vital Attraction and Repulsion.† But this can only, at present, be regarded as a conjecture, to prompt farther inquiry. And we cannot suppose the muscular fibres to consist, as some have thought, simply of strings of globules, because in the cold-blooded animals they are of much smaller diameter.‡

The important fact already mentioned as having been lately ascertained by Magendie, that blood which has lost the power of coagulating constantly transudes from the

* See Prater's Experimental Inquiries, &c. p. 118, *et seq.*

† See Black on Capillary Circulation and Inflammation, p. 87; and Prater's Experimental Inquiries, &c. p. 19 and 214.

‡ See Muller in Ann. des Sciences Nat. 1834, p. 353.

capillary vessels, may probably be regarded as an indication of the importance of a Vital Attraction among the particles of the fibrin. It does not appear possible to ascribe that fact to the mere circumstance of attenuation of the blood which has lost its fibrin. 1. Because no such extravasation of the colouring matter of the blood resulted in his experiments from great attenuation of the blood by injections of pure water, and 2. Because the extravasation took place when an alkaline solution was injected into the veins in such quantity as to destroy the coagulating power of the fibrin without materially attenuating the blood.* It is to be observed, however, that the tendency to coagulation shewn by the blood does not appear to be always in accordance with its properties when circulating in the vessels. Thus, although the extravasations of blood which occur in Scurvy and Purpura, are generally connected with a fluid state of the blood drawn from the veins, yet there are cases of the latter disease in which the blood that has been drawn coagulates firmly. On the other hand, a case is given by Magendie of an animal in perfect health, in which the blood shewed no tendency to coagulation.† Such varieties afford farther evidence that the condition of the blood as to the property of coagulation is not the effect of simply physical causes.

The important changes which take place, sometimes in portions of the blood itself, effused from vessels in the living body, but much more generally in portions of fibrin, effused from inflamed surfaces and becoming organized, may also be held as clear indications of certain vital properties in the blood, which are modified and exalted by disease, although little progress has as yet been made

* Leçons, &c., t. 3, p. 329, *et seq.*

† Leçons, &c., t. 4, p. 244.

in determining the precise nature of these properties. It is certain that the particles of fibrin which thus escape from the vessels and form preternatural membranes, are held together by an aggregating force, much greater than existed among them in the fluid blood; that globules of blood effused into the dense but soft cellular substance thus formed, follow each other, with gradually increasing velocity, in tracks which soon become vessels; and that the lymph composing that substance is liable to conversion, perhaps into globules of blood, certainly either into pus, or other morbid products, in the event of the disease continuing,—or into natural textures similar to the adjoining parts when health is restored; all which phenomena come clearly under the definition of Vital Action.†

The same observation may be applied to the masses of fibrin so frequently found in the heart and large vessels after death, which, when completely decolorized, have probably been gradually formed before life was extinct, and have often been found to exhibit variety of structure, and even similarity to the products of disease in other parts of the body; ‡ and perhaps the formation of phlebolites or earthy concretions in veins is by a process of the same nature.§

The part of the blood chiefly concerned in, and perhaps the only part essential to, nutrition, is the Liquor Sanguinis; and of the use of the globules of the blood (which do not generally or necessarily leave the circulating vessels) we have no satisfactory information.

* See Hunter on the Blood vol. ii. p 61.

† See particularly Gendrin, Hist. des Inflamm. &c. § 1566, *et seq.*; Kaltenbrunner, Exp. circa Statum Sang., &c. p. 22, *et seq.*

‡ See *e. g.* Andral and Lobstein; and Graves in Dublin Journal, 1835.

§ See Dr J. Reid in Edin. Med. Journ. 1835.

But the great proportion which the globules bear to the other solid constituents of the blood, and the languid condition of those persons in whom their quantity is deficient, sufficiently shew that they must be of essential importance in the animal economy. From the effects of transfusion in the experiments of Dieffenbach and others, they appear to be more effectual as stimuli to the heart's action than any other part of the blood; and some curious facts have been ascertained as to the effect of transfusing the blood of one animal into the vessels of another belonging to a different order, and of which the globules have a different form. This operation has generally been fatal; in the experiments of Bischoff it appeared that the injurious effects depended not on the globules, whether larger or smaller than those of the animal under experiment, but on the fibrin,—blood deprived of its fibrin having no such injurious effect;* but from the experiments of Magendie, it appears probable that the fatal effect had been owing to coagulation of blood during the process; for he injected the blood of quadrupeds into birds, and that of frogs into quadrupeds, without injury, where this accident was avoided. And the important fact was thus ascertained, that the globules of the foreign blood thus introduced into the vessels of an animal, were in a very short time assimilated to those of the animal receiving them, the oval globules of the bird or of the reptile disappearing in the blood of the quadruped, and vice versâ,† which is decisive proof of the important part of the process of assimilation which goes on within the bloodvessels.

Arterial blood has been ascertained to differ from venous not only in its colour being scarlet, instead of purple, but also,

* Baly's Muller, p. 141. † Leçons, &c., t. 4, p. 365, 376, 387.

1. In containing more oxygen and less carbonic acid, as will appear from facts to be stated under the head of Respiration.

2. In coagulating both more quickly and more firmly.

3. In the crassamentum formed in it, and especially the fibrin of that crassamentum, bearing a larger proportion to the whole blood.

The proportions of the solids of the crassamentum given by Denis are 995 to 970, while the solids of the serum are more abundant in the venous blood, as 730 to 735.*

The quantity of fibrin in Arterial blood seems to be nearly 1-5th more than in venous; the proportions given by Muller are 483 to 395.†

It is obvious, from these facts, that the fibrin is expended in a considerable degree in the course of the greater circulation, and renewed probably from the lacteals and lymphatics. It is equally certain, that the globules, which are formed in large numbers in the organs of digestion, and yet do not accumulate in the blood, but diminish in the course of the circulation, must be either decomposed or deposited in that course; and so far as microscopical observations enable us to judge, they are more probably decomposed than deposited entire. Indeed the decomposition of opaque globules and formation out of them of a transparent semifluid matter, seems to be one of the earliest of the vital operations in the embryo.‡ But we have no precise knowledge as to these processes in the adult. It has been lately stated, as the result of many microscopical observations by Schultze, that the addition of oxygen to the blood, by respiration, enables the liquor sanguinis (or Plasma), gradually to decompose the globules, by attracting out of them their

* Recherches Experimentales sur le Sang, p. 254 and 285.

† Baly's Muller, p. 114.

‡ See Burdach's Physiol. § 398.

central nuclei; that it is thus rendered fitter for the nourishment of the textures; and that the globular or vesicular part of the blood, thus altered, may be detected in the venous blood, particularly in that of the Vena Portæ, which is probably thus rendered fitter for throwing off the bile. But the observations on which this speculation is founded, have not yet been confirmed by others.*

The greater proportion of fibrin, and more rapid coagulation, after what has been stated above, naturally lead us to suppose that the vital properties will exist in arterial more than in venous blood; and accordingly, it is with the circulation of arterial blood through the different textures, almost exclusively, and with the separation of portions of the arterial blood in them, that the other vital phenomena of the living body are connected.

It is in accordance with these facts, that the blood of cold-blooded animals differs from that of warm-blooded, in the globules being larger and less numerous (therefore capable of less action with the air), and in the crassamentum, and the fibrin particularly, being in less proportion to the other constituents. But according to the recent statements of Berthold, there is no such regular gradation in these respects, as Prevost and Dumas had supposed.†

* See L'Institut. Sept. 1838.
† See Burdach's Physiol. § 774.

CHAPTER VI.

OF NUTRITION, EXHALATION, AND SECRETION IN GENERAL.

The fundamental and essential function of Nutrition is carried on in the different classes of animals with a rapidity nearly proportioned to the complexity of their structure, and to the energy and variety of vital actions of which they are susceptible.* Wherever a circulating system exists, it is the agent employed for that purpose. For although the existence of arterial branches, terminating in exhalant surfaces, in secreting organs, or in the solid textures, has been nearly decisively disproved;† and although the observation of the actual escape of globules of blood from the circulating vessels, and their application to any of the animal textures, has been described by few microscopical observers, and does not appear to be essential to the nutrition of any texture; yet the following considerations leave no room for doubt, that portions of the circulating blood are continually applied to the formation and support of the solids and other fluids of the body, and that, in so far as these are dependent on such supplies, they receive them from the blood.

1. The formation of many of the fluids, and some of the solids of the body, is continually going on; as that of all parts of the body is, during the time of growth. There is also good evidence, to be afterwards stated, of

* See Tiedemann, Traité de Physiologie, § 298, *et seq.*

† See Baly's Muller, p. 214.

continued absorption from all parts of the body, without loss of substance, which implies continued deposition.

2. While these facts shew that something is continually added to the solids, and other fluids of the body, it is equally clear that something is continually abstracted from the blood; because continual additions are made to it from the organs of digestion, without permanent increase of its quantity; but this is quickly diminished when those supplies fail.

3. The blood is continually applied to the solids, and to the prepared fluids of the body, in capillary vessels which must easily admit of more or less transudation; and is materially changed by that application.

4. The blood is fitted by its composition, for supporting the different animal solids and fluids; and we have actual proof of its application to these purposes, in case of the increased exhalation or artificial dropsy, produced by injection of water into the vessels, in many experiments of Magendie and others; and in many cases of wounds healed, swellings formed, or adhesions contracted, evidently by blood or lymph effused from vessels in a state of inflammation, and becoming organized.

5. Increased growth, natural or morbid, of any part, is always attended by enlargement of its vessels, and the vascularity of those textures, in which fluids are continually formed, is always much greater than that of those, in which solid matter only is contained.

The term *Nutrition* is generally applied to the deposition of solid matter from the blood, and the term *Secretion* to the formation of fluids; this last being divided into *Exhalation*, where the fluid is thrown out on an extended surface, and Secretion properly so called, where it is prepared in a gland, and carried off by a duct.

All that is known of the course of the portions of blood

destined to these purposes is this: It passes, in all these cases, in numerous capillary vessels, with very thin coats, often in channels, not to be distinguished from the surrounding textures, along the surface of membranes, along the septa of cells, or in the interstices of fibres. A membrane, on which many vessels ramify, seems all that is necessary to any kind of secretion; and all the varieties of secreting organs to be only "contrivances for conveniently packing a large extent of such a surface in a small compass.*" These vessels, so far as they can be traced, either in the living bodies of animals, or after the most successful injections with size and vermilion, pass on to the veins. It is very doubtful whether the particles of vermilion ever escape from them except by rupture; and any extravasations from them in the natural state, would seem to be, not through visible outlets, but by *lateral pores.*

These facts are strongly stated by Mascagni, Schultze, Du Trochet, Prevost and Dumas, &c., and the statement is fully confirmed by the minute anatomical investigations of Prochaska,† Dollinger,‡ Breschet,§ and others, and by the elaborate and satisfactory work of Muller, "De Glandularum Secernentium Penitiori Structura;" so that the apparatus employed for nutrition and secretion in all parts of the body seems to be essentially the same; and the process to be nothing more than the exudation of one set of particles in one place, and others in other places, from the mass of circulating blood, or, as Du Trochet expresses it, a Chemical Filtration.||

* Mayo.

† Disquis. Anat. Physiol.

‡ De Vasis Sanguif. quæ villis intest. insunt.

§ Recherches sur les Appareils tegumentaires, &c. Ann. des Sciences Nat. 1834, t. ii.

|| "Sanguis in omnibus organis per minima vasculorum sanguifero-

It is an important question, whether the different textures and secretions of the body are actually *formed* from the circulating blood, at the parts of the body where they appear, or are formed previously in the blood itself, and only *evolved* or separated at these parts. The following facts strongly favour the last opinion.

1. The general law of living animals, and probably of vegetables also, formerly laid down,—that all nourishment received from without must be mixed with secretions of the organized body itself, and so far elaborated in its interior, before it is applied to the support of any part of the organization,—makes it probable that an important part, at least, of the process which fits it for giving that support, is completed before it reaches the organs where it is so applied, and facts already stated as to the blood shew that it may be much changed within the vessels.

2. As the blood contains, or shews after the simplest chemical processes, Fibrin, Albumen, Muco-Extractive Matter resembling Osmazome, Water, Oil, probably some of the materials of the Bile, certainly the phosphates of Lime and Magnesia, and most of the other salts found in the secretions, it appears fitted to yield, by mere sepa-

rum retia ex arteriis in venas transit. Quæ retia undique clausa sunt, solasque in advehentes arteriolas et venas revehentes aperiuntur." "Tenuissimi sanguinis in vasculis illis reticulatis rivuli vix spissioribus substantiæ limitibus tanquam parietibus continentur; membranæ enim propriæ hic nondum adsunt vasculis. Oriuntur iterum iterumque novi per substantiam rivuli," &c. "Substantiam ad rivulorum limites, parietum adinstar, spissiorum adesse, hoc equidem non videmus, sed licet suspicari. Verum ex spissiori solummodo substantiæ limite parietes hice, nec vero membranis constare possunt, tamque parva intercedit inter rivulum continentemque substantiam differentia, ut substantia liberum cum sanguinis rivulis ineat commercium." Muller, Op. Cit. lib. 15.

ration of its constituent parts, by far the greater part of the substances found in the textures and secretions of the body.

3. It has been ascertained, first by Prevost and Dumas, that, when the secretion of urine is suppressed by extirpating the kidneys of animals, the Urea, which is the characteristic part of that secretion, may, after a time, be detected in the blood; implying obviously, that it is always formed in the course of the circulation, not in the kidneys; and the same has been found in the human body, in the blood, and in the serous exhalations, in some cases where the secretion of urine has been much obstructed by disease, whether functional or organic, of the kidneys.*

We know that there are cases of Jaundice in which no obstruction exists in the passages for the descent of the bile, and none seems to be secreted at the liver. It is probable, that in such cases the formation of the bile is, in like manner, merely multiplied in the blood, from the loss of vital power in its usual outlet, as happens to the urea when the kidneys are extirpated, or in Ischuria Renalis. It would appear also, that in both cases the retained excretion acts very surely as a fatal poison; and it seems therefore probable that excretions *retained* in the blood are more injurious than those *reabsorbed* into it (as in the more common case of jaundice);† and some facts known as to the function of absorption support this supposition.

4. There are various instances, in disease, not only of textures widely extended over the body, such as Bone and Fat, being deposited in unusual situations, but also

* Bostock's System of Physiology, vol. iii. p. 412. Christison, Edinburgh Medical and Surgical Journal, vol. xxxii. pp. 271 and 274.

† See Edinburgh Medico-Chir. Trans. in Edin. Journal, 1835, p. 293.

of substances usually secreted in special organs only, such as Cholesterine, being deposited in parts distant and very different from those where they are commonly found; and even independently of structural disease, there are various well authenticated cases on record, where secretions, especially those of urine and of milk, have been thus established, and passed off for some time, "per aliena cola."*

5. It is often observed, in cases of disease resulting from the introduction or retention within the body, of noxious or unassimilable matter, that this morbific matter, certainly mixed with the whole blood, is evolved from the circulation at certain parts, or in certain textures rather than others; which implies a peculiar relation of foreign matters, circulating with the blood, to the vital properties of peculiar textures, and makes it probable, that there exist similar relations of textures to the different natural constituents of healthy blood.

6. There is so much provision in all the higher animals, for the *very gradual* incorporation of the crude ingesta with the blood (to be noticed under the head of Absorption), that we have every reason to suppose the blood-vessels to be the scene of many chemical changes, and the blood to be a fluid of as complex a nature as this supposition implies.

It has, indeed, been observed, on the other hand, that

* Setting aside, as inapplicable here, many of the cases recorded under this head by Haller (Elem. Lib. 7. C. 1), there remain several which seem to justify this observation; and various similar cases have been recorded since, *e. g.* in Magendie's Journal de Physiologie, vol. vii.; and London Medical and Physical Journal, June 1828; two by Dr Crampton, in Dublin Hospital Reports, vol. v.; and a remarkable one by Dr Peebles, in Edinburgh Medical and Surgical Journal, 1835.

a conclusion resting on observations made on the secretions of urine, bile, and milk, which are destined to excretion, is not necessarily applicable to the case of those formations from the blood which are destined to useful purposes in the animal economy; that several of the other elements of the animal textures found in small quantity in the blood, may be supposed to be the products of *Absorption;* and that it is doubtful whether the Fat of the animal body, or the Nervous Matter, can be recognised in the Blood, and certain that the Gelatin, which is easily procured in abundance from any animal textures, cannot be recognised there, at least by the simple methods of proceeding formerly specified.

But the force of this last argument is in a great measure done away by the fact, that the Urea cannot be detected in the blood until its excretion by the kidneys is stopped, and then uniformly appears; from which it seems fair to infer, that other substances habitually deposited from the blood may exist in it ready formed, but in so small quantity, at any one time, as to shew themselves only when their deposition is arrested.

It is true also, as stated by Cuvier, that in many Zoophyta, where secretion and nutrition are seen in their simplest forms, the general nourishing fluid, formed and contained in one internal cavity, appears to furnish products very different from itself, by a process hardly more complex than mere transudation through a living membrane;* but even in such Zoophyta there is often a circular movement of fluids. Besides, their structure is so simple, that little variety of products requires to be formed from the nourishing fluid; and as there is in the central cavity of these animals a mixture of nourishment from without, with the fluids of their internal

* Cuvier, Leçon 23, sect. 2. art. 5.

surface, and a pretty free exposure to the air, all the conditions necessary for effecting much chemical change on the ingesta, are present in a greater degree than in any one part of the internal cavities of the higher animals; and it may therefore be supposed that new products are formed in that cavity, before the nourishment by imbibition begins.

We ought to admit, however, that although the products formed in the living body are probably so far elaborated in the blood itself, yet, in various instances, a material change may be effected in these products at the time and place of their escape from the circulation.

It has been denied, that Transudation takes place at all through textures in the living body, and this idea favoured the supposition, that all Secretion and Nutrition must be by branches of arteries specially designed for that purpose; but the occurrence of transudation through living textures, which was maintained by Dr W. Hunter and by Mascagni, has been put beyond doubt by the experiments of Magendie and others. It appears, however, that it takes place to a less extent than in the dead body: and the escape of fluids from the vessels, in particular, must be impeded, and may probably be variously modified, by the exercise of their tonic power, formerly considered.

There has been much farther speculation as to the explanation of the formation of so many different compounds in the living body from the same blood; but inquiries on this subject have led to results, which, though very important, are for the most part negative.

I. The blood, in its passage to the different organs, is propelled, through canals of extreme minuteness, various-

ly contorted, and of very various length, and endowed, perhaps variously, with power of acting mechanically upon it; and the frequent alterations of the distances and positions of its particles, thus effected, have been supposed to be a sufficient cause for the variety of products which it yields. * But the insufficiency of this explanation is unequivocally shewn by the following facts.

1. It appears from the cases mentioned, that Secretions may pass out for a time, by organs distinct from those at which they generally appear, and this without perceptible change of structure, or subsequent alteration of the functions, of the parts that take on this new kind of action.

2. Substances the most widely different in composition from the blood, such as Bone and Cartilage, are formed in parts of the human body where there is no very complex arrangement of vessels; and very complex arrangements, in various parts, yield products but little different from the serum of the blood. In many of the lower animals, and vegetables, no varied system of vessels, nor even any perceptible variety of cellular structure, is employed for the formation of very various compounds.

3. Even in different parts of the human body, and still more on examination of various animals, it appears, that products very nearly resembling each other, and answering the same ends, are formed in organs where the structure and the disposition of the vessels are very various; and again, that substances the most widely different are formed in organs that are in these respects extremely similar.†

4. It is quite certain, from numerous microscopical ob-

* See *e. g.* Murray's Chemistry, vol. iv. p. 518.

† Cuvier, Leons, t. 5, p. 214.

servations, that in the primordial state of animals, especially cold-blooded, not only the general form is given, but the nutrition of most parts,—of the bones, muscles, nervous system, of the organs of digestion and secretion,—is so far advanced, before either blood or bloodvessels are formed.

It would even appear, that instead of the form of the bloodvessels determining the matter to be deposited from them in each part of the body, it is the nature of the texture formed in each part, that determines the number and form of the bloodvessels supplying it. For no bloodvessels are ever seen, in the fœtal state, empty of blood, but when the blood enters the organs, of which the germs have been already formed, it makes passages for itself, which become vessels; and in so doing, it does not diffuse itself equally in all parts, as if propelled by a *vis a tergo*, but follows a different arrangement in every different organ, a very different arrangement, *e.g.* in the brain, from that in any secreting organ; and the size, number, and form of the vessels entering each organ are obviously determined, not by the size of the organ, but by the nature of the vital action which goes on there, as appears, *e.g.* on comparing the kidney and testis. Thus, not only each organ appears to attract the blood into it, and to act peculiarly on its constituent parts, but each appears to modify the course which it follows in entering it.*

II. As Secretion is much influenced by causes acting on the Nervous System, and especially by injuries there inflicted, it has been and still is supposed by some physiologists, that it is necessarily dependent on some power communicated through the nerves from the brain and spinal cord. But to this theory of dependence on the

* See Burdach, Physiol. § 759.

brain and nerves, the following appear nearly insurmountable objections.

1. Secretion and Nutrition are phenomena observed much more generally in nature, than any vestiges of nervous matter; viz. not only in those animals where no nervous system has been detected (which must be allowed to be a doubtful case), but in the whole vegetable kingdom; in which they are at least as numerous, varied, and striking, as in the economy of animals.

2. Secretion and Nutrition take place after the usual manner, in the case of the human fœtus without a brain, —in that of the fœtus without either brain or spinal cord, —nay even in the fœtus, which has hardly a vestige of nervous matter in its composition.*

3. It appears from the inquiries of different anatomists, particularly of Tiedemann and Gmelin, of Serres, of Baumgærtner, and others, that the formation of the larger masses of the nervous system in the fœtus, is always posterior to acts of nutrition, different textures being already nourished in every part, before nervous matter is distinctly formed there.

4. Such injury or disease of the nervous system as destroys all voluntary motion and sensation of a limb, and materially affects the pulse there, although it usually modifies, does not stop the nutrition or the secretions there, nor prevent the usual effects of inflammation, which are analogous to secretion, from taking place; and in different experiments of physiologists, when the nerves of secreting organs were cut (*e. g.* of Bichat on the Testicle, and Mayo on the Kidney), secretion in these organs, although sometimes altered, was not suspended.†

In opposition to these facts, the experiment (familiar

* Clark in Phil. Trans. 1793.

† It is true, that in experiments by Naveau, by Brachet, and by

to Haller, but often repeated and varied by Dr Wilson Philip, and others), of cutting the 8th pair of nerves in the neck, and thereby arresting the digestion of food, which implies suspension of the secretion of the stomach, is surely too slender a foundation for the general assertion, that a nervous influence is essential to all Secretion.

Farther, the conclusion thus drawn from that experiment, is liable to the following objections:

1. The result of the experiment is not uniform; for the trials of Breschet and Edwards, those of Leuret and Lassaigne,* and more especially two experiments performed with scrupulous care, by Dr J. Reid at Edinburgh in 1838, seem sufficient to establish the positive fact (necessarily much more conclusive in this inquiry than any negative fact), that after the section of those nerves, with loss of substance, in the neck, and without the aid of galvanism, digestion may, in certain circumstances, be carried on.

The secretion at the stomach is peculiarly under the influence of Sensation, as well as of emotions of Mind, nay, the formation of the acid liquor, which is the main agent in the process,—as we shall find that it takes place only on certain occasions, and for useful purposes only after food has been taken,—may probably be, in the natural state, really dependent on certain sensations. The effect of this operation is not only to cause pain, but to excite

Muller, the secretion of urea at the kidney seemed to be suspended, and the action there reduced to simple hæmorrhage, by cutting or destroying all the nerves of the kidney; but this was only when such violence was done as the separation of the whole kidney from the body, leaving the blood passing through a quill, the only medium of communication, in which case the whole vital properties of the solids composing the kidney may be supposed to have been destroyed,—or such violence as obviously softened and disorganized the organ.†

* Recherches pour servir à l'Histoire de la Digestion, p. 133.

† See Brachet's Recherches Exp., &c. p. 276, *et seq.*, Baly's Muller, p. 471.

much nausea, and afterwards dyspnœa, which is fatal within two or three days. Such sensations, however produced, will materially affect that and other secretions, but do not prove the necessary dependence of the secretions, on the parts by the injury of which they are excited. When the branches of the 8th pair going to the stomach were cut on the œsophagus by Magendie, the effect on the lungs and the dyspnœa not being produced, the secretion at the stomach was not arrested.

3. In all experiments made by cutting the nerves in the neck, it has appeared, that while the secretion at the stomach was suspended or diminished, the secretion in another part equally supplied by these nerves, viz. the bronchiæ, was altered and *greatly increased.*

4. In Dr Wilson Philip's experiments, the secretion of the stomach, suspended by the operation in the neck, was restored by Galvanism. The result is therefore conclusive *against* any influence from nerves being essential to secretion, unless it were proved that nervous influence is identical with galvanism. Now this is not proved; and if it were, it would give little assistance in explaining secretion ; because galvanism is a *single* known chemical agent, and the difficulty is, to explain the evolution of *many and various* chemical compounds, in different parts of the body, from the same blood.

III. The reference made by Bichat, of the phenomena in question, to the property which he called Organic Sensibility, and likened to Sensibility properly so called, is also quite unsatisfactory ; because the term sensibility, and all principles connected with it, are inapplicable to changes which are unattended by any Sensation.

It appears on the whole, beyond doubt, that the phe-

nomena of Secretion and Nutrition are inexplicable by, and inconsistent with, any principles that can be deduced from the observation either of dead matter, or of other functions of the living body. At the same time, it is obvious that they do not take place fortuitously, or at random, but according to fixed laws. We refer them, therefore, to a Vital Property, known to us only by its effects, and our notion of which is, as yet, necessarily vague and imperfect;—which modifies chemical affinities in the living body;—varying in each different organ and texture of the body, and causing these to be differently affected by, and produce different effects on, the blood that pervades them;—influencing thereby, also, the chemical nature and relations of the blood itself. To this property, the best name that has been given is VITAL AFFINITY. This Affinity must obviously exist chiefly between the solids of the body in each organ, and certain of the component parts of the blood; and it is important to observe, that various facts prove it to be efficient in attracting these portions of the blood from the vessels to some distance along the solid textures. Thus, when the blood stagnates in an aneurismal sac, its outer layers, which are farthest from its still fluid and moving portions, are first decolorized, which can only be by an agency of the living solids in contact with them.* Indeed, microscopical inspection of the circulation in the fin of a tad-pole, or wing of an insect, is enough to shew, that the power by which portions of the blood are applied to the nourishment of living solids, must extend its action to some distance from the only circulating vessels then existing. The existence of this power, will always be an ultimate fact in Physiology; but the limits of its agency, and the laws according to which it modifies the chemical relations of the

* Burdach's Physiol. § 758.

substances subjected to it, may be ascertained; and their development will probably constitute the next great discovery in this Science.

Dr Prout has lately laid down the following principles, as to the formation of organic compounds in living bodies, which, if duly established by observation, will be so many steps in this inquiry.

1. That all organic compounds are formed by the same affinities, which exist among their elements when existing in inorganic forms, but that, in the vital processes by which they are formed, some of the ultimate particles of bodies are excluded, and others brought into contact, according to the object to be attained, so as to give a different *effect* to these affinities, from those which they can produce in other circumstances.

2. That it appears to be essential to the formation of organic compounds, that the elements composing them should not unite so as to form crystalline substances, and that probably no crystallizable body is capable of constituting a portion of a living organized being; such products, when they do occur, being either the result of excretion, or of disease, or of some artificial process.

3. That the small quantities of earthy and saline substances existing in all organized bodies are probably essential to their organization, and that by their union with the other elements of the organic compounds, these last may probably be effectually deprived of the power of crystallization or *mcrorganized*.

4. That all organized beings appear to be essentially constituted by compounds which may be referred to three great natural classes or groups, the Albuminous, the Saccharine, and the Oleaginous; and that in each of these the elements are combined, not according to certain definite proportions only, but in proportions varying at the

terms of certain series of numbers (such as the series, 3, 6, 9, 12, &c.).*

In the mean time, several well-known facts, besides the phenomena of Secretion and Nutrition themselves, illustrate the general principle, that the vessels, and the powers that move the blood in the vessels (one of the most important of which appears from what has been said, its more attractive powers, exerted by the living solids), are differently affected in different organs and textures of the body, by the blood that pervades them, or by substances conveyed to them by this blood. Of this kind are,

1. The difference, already mentioned, between the flow of arterial and venous blood through the vessels of the lungs; while both pervade with ease the substance of the liver.

2. The fact, that textures which shew nearly an equal degree of vascularity after fine injection in the dead body, habitually admit very different quantities of blood in the living body.†

3. The specific effects of various poisons, and contagious effluvia, circulating in the blood, on individual glands or individual membranes only.‡

The widely different effect of various substances (*e. g.* of Air) applied externally to the vessels of serous and of mucous membranes, must be referred to the same general principle.

* See Lectures in London Medical Gazette, vol. viii.

† See Bichat, Anat. Gener., tom. ii. p. 479, and Burdach's Physiol.

‡ The experiments of Dr Percy (Prize Thesis, Edinburgh 1838) seem to have established the fact that alcohol, circulating in the blood, has a peculiar tendency to fix itself in the brain and in the liver.

CHAPTER VII.

OF ABSORPTION.

That Absorption, both of solids and fluids, takes place frequently, and to a great extent in the living human body, and in the most analogous animals, is easily proved.

1. By the wasting of the whole body, or of individual parts of it, which no external agents can affect, observed in various circumstances of health and disease.

2. By the disappearance, whether spontaneous or determined by art, of fluids which had been perceived in various parts of the body, or been injected into the cavities of the body.

3. By the effects produced by various substances placed in contact with any living surfaces, exactly similar to those produced by them when received into the stomach or injected into a vein.

We first state what is known of the agents by which this Absorption is effected, and afterwards endeavour to estimate the extent to which it is carried on, in the living body.

I. The vessels called Absorbents were, for a time, thought to be the only agents, and are still thought to be important agents, in this work of absorption.

These vessels are similar in appearance to the smaller veins, but are of more delicate texture; their coats are not distinctly divisible into different layers, but are very distensible, tough, and elastic. They are also more fully

provided with valves, and of more irregular diameters, than the veins. Their smaller branches anastomose very freely, and are very numerous in many textures of the body; but there are some textures, as the Bones, in which they can hardly be traced, and others, as the contents of the Cranium and the Nervous System generally, in which they have not been detected. They are divided into the Lacteals, which come from the intestines, and the Lymphatics, which come from other parts of the body.

In the human body, all the vessels which can be distinctly recognised as lacteals or lymphatics, pass somewhere through the small oval-shaped bodies called Conglobate Glands, most of which are set together in clusters in the hams, groins, axillæ, on the sides of the neck, in the posterior mediastinum, besides the iliac arteries and aorta in the pelvis and abdomen, and in the mesentery. Several branches of these vessels enter and pass out of every such gland; and they are so intimately subdivided and reunited within its substance, that every branch leaving it appears to be in communication with every branch that entered it. Every gland is likewise fully supplied with blood from arteries, which are minutely subdivided and convoluted within it.

These vessels unite after the manner of veins, and, when traced to their termination, lead to two points in the vascular system; those where the internal jugular and subclavian veins meet, on each side of the neck. The trunk, which terminates here on the left side of the body, has its chief supply from the thoracic duct, which ascends beside the aorta in the abdomen and thorax, from the vertebræ of the loins.

The contents of the lacteal vessels will be considered under the head of Digestion. The fluid contained in the

lymphatic vessels of animals, and in the thoracic duct of those that have fasted long, has been found very various in quantity, and somewhat various in qualities; but in general, of fully as low specific gravity, and containing as little animal matter, as the serum of the blood, and nearly resembling it in chemical composition; with these remarkable differences, however, that a number of globules, similar to those of the blood, are observed in it; and that it contains a small quantity (not more than one-half per cent.) of fibrin, and therefore coagulates where emitted. It has sometimes a reddish colour, and becomes florid on exposure to air, especially in animals that have fasted long. In such animals it is most abundant; but when weakness has been brought on by inanition, its quantity is again diminished.*

That the movement of the fluid contained in these vessels must be towards the great veins, is shewn by the structure of the valves, which will not admit of motion in an opposite direction, unless the vessels are much dilated. Although the motion is slow, the fluid is propelled with force. The vessels contract and empty themselves when punctured; and when the thoracic duct has been tied, it has generally been ruptured by the distention below the ligature.†

The structure of the lymphatic and lacteal vessels, and of their glands, in the different classes of animals, and their connexion with the veins, have been carefully investigated of late years, especially by Lauth, Fohmann, Muller, and Panizza; and the most important results of their observations are as follows:—

1. It would appear, that the previous representations

* Collard de Martigny, in "Journal de Physiologie," 1829.

† Sir E. Home, Phil. Trans. 1811.

of lacteals and lymphatics commencing by open mouths from the surface of membranes, or the interstices of fibres, or substance of textures, are probably erroneous; no such openings having been seen on the villi of the intestines by the careful inspection of Meckel or Rudolphi, Dollinger or Lauth; nor on the surface of the skin by Breschet;* and none having appeared in the finest injections of Fohmann or Panizza, by which the lacteals were the most completely filled, unless rupture could be traced.†

2. The notion of Magendie and others, that communications may exist between the smallest arteries and the lymphatic vessels, appears to be satisfactorily refuted; the finest injections of Panizza coinciding with those of Mascagni, in shewing, that the smallest lymphatics are never continuous with the smallest bloodvessels, and even that they are ten times as large.

3. The opinion of many anatomists, as Abernethy, Bracy Clark, Tiedemann, Fohman, Lauth, Lippi, &c. of communications existing between the lymphatics and many of the veins in Man, and others of the Mammalia, if not absolutely refuted, is strongly opposed by the fact, that such communications between any vessels which are certainly lymphatics, and veins, were never found by Panizza in any of the Mammalia, excepting only in the great veins of the neck; and although this negative fact may not seem sufficient to set aside positive observations, yet as a source of fallacy is pointed out, in the circum-

* Ann. des Sciences Naturelles, 1834, p. 208.

† The observations of the late Dr Gordon on the Lymphatics of the Skin were to the same purpose: "There is no appearance of distinct origin any where among the lymphatic vessels of the true skin, and I have never seen the smallest particles of the quicksilver escape from the outer surface in the most successful injection."—*Syst. of Anat.* p. 234.

stance of many small veins, leading from lymphatic glands, being easily filled by injections from the lymphatics, the positive observations of former anatomists may be distrusted.

In most birds and reptiles, however, it appears that there is a uniform communication between the lymphatic vessels of the lower extremities and the great veins of the pelvis; and in the frog a similar communication below the scapulæ. Where this communication exists, the lymphatics are enlarged into vesicles, and in the reptiles (where the lymphatic vessels are more numerous and larger than in any other animals), these vesicles pulsate like hearts.*

4. In the lymphatic glands (which are nearly confined to the Mammalia, and may be thought to answer a similar purpose as these communications with the bloodvessels in the lower tribes), the observations of Panizza go to confirm what had been previously supposed, that intermixture of the contents of the lymphatics and bloodvessels must take place by transudation; for he found that mercury injected into the lymphatics passed very generally, without violence and without apparent rupture, into the veins, although with different facility in different animals.

That Mr Abernethy was mistaken, however, in the supposition that large cells or sacs exist in the mesenteric glands of the whale, into which both bloodvessels and lymphatics open, appears from the observations of Dr J. Reid, who found them to contain no distinct cells, and to be of the same structure as in other mammalia.†

If we consider it ascertained, that lymphatics and lacteals originate in a network of vessels, and have no open

* Muller, Phil. Trans. 1833. Edin. Med. Journal, 1835.

mouths, we must suppose that into them, as well as into veins, the matters they absorb enter by transudation, but not by what is usually called capillary attraction.* It has been stated that they are filled by a kind of Endosmose, *i. e.* by reason of the relations of the fluids exterior to them to the fluids within them. But the rapidity of the action of absorption in the living body, its cessation in the dead body, and the *selection*, to be afterwards noticed, in the primæ viæ, of thin fluids by the veins, of chyle by the lacteals, and the rejection of the biliary matter in the natural course of digestion by both, are sufficient to distinguish this vital action from the endosmose and exosmose of dead matter.

It has been lately supposed by Mojon, that fibres, both longitudinal and transverse, can be seen in the coats of lymphatics, which may be thought to act on their contents in the same way as the intestines, or the dorsal vessel of articulated animals; but the investigations of Breschet† seem to have decided this point in the negative.

Now, if we find the best anatomists think that the absorbent vessels have no open mouths, and can only be filled by transudation,—if we cannot find that they have any vital power but that of tonicity or simple contractility like the arteries, which must obstruct rather than assist the entrance of foreign matters into them,—and if we consider farther that absorption in the lowest animals and plants takes place to a great extent, without any

* Absorption seems every where to take place, as expressed by Breschet, "par l'imbibition prealable du tissu;" and if there be any orifices in the sides of the smallest lymphatic vessels, "ils doivent avoir une bien grande capillarité, puisqu'ils refusent passage au mercure." (Op. cit. p. 224.)

† Ann. des Sciences Naturelles, 1834, p. 236.

vessels being assigned to the office, or contractile solids concerned in it,*—we can hardly hesitate as to the conclusion, that the force by which this function is carried on, does not consist in contractions of the coats of the vessels concerned in it, but is rather to be referred to the head of Vital Attraction and Repulsion. It appears from these statements, that the organ of absorption, equally as of nutrition or secretion, is not a vessel, but is the membranous or parenchymatous lining of a vessel, impervious to the mercury by which the vessel itself may be filled and distended; and when we reflect on the *activity*, and on the *selecting power* (in certain instances), of such an absorbing apparatus, we must admit, that a principle of motion, independent of contraction, must be concerned in the function.

Even supposing all these vessels to arise by open mouths, from the surface of membranes, the interior of cells, &c. although the principle of Capillary Attraction would be a sufficient cause for the ascent of the fluids along them; yet the influence of this cause alone could never call into action the elasticity of the vessels, to promote that ascent; because the effect of capillary attraction is fixed and uniform; and in order that the elasti-

* The most striking examples of this that have been carefully observed, are the absorption by the motionless spongioles at the ends of the roots of vegetables, and by their rigid heart-wood, described by Du Trochet,† and the absorption of the polypi at the ends of the branches of the Sertulaviæ, described by Mr Lister.‡ In neither case could the slightest contraction of solids be perceived; and in the latter case it seems quite certain, that no other movement than an attraction in the general direction of the current going on in the transparent stem of the creature, attended the absorption of the living structure at its extremity.

† L'Agent Du Mouvement Vital devoilé, &c. p. 103.

‡ Phil. Trans. 1834, p. 3, pl. 9.

city of a tube may be a cause of motion in its contents, it is necessary that the other forces propelling these should be variable or intermitting.

Neither could the ascent of the fluids contained in these vessels, if dependent on capillary attraction, be aided by the action of the valves; because a fluid drawn up into a set of tubes by this cause alone, has no tendency to recede; and the only use of a valve is to prevent recession of fluids.

The structure and the elasticity of these vessels, therefore, and the principle of capillary attraction, are quite inadequate to explain the momentum, which the facts above stated shew, that the contents of these vessels in the living body possess; and no other cause can be assigned which, on merely mechanical principles, will explain these phenomena. We are therefore constrained to believe, that the fluid in these vessels is moved by powers which are strictly Vital; but that no vital contractions, of which these vessels are susceptible, suffice for the explanation of this motion, seems sufficiently established.

Some doubt has been thrown over the general opinion as to the office of Lymphatics strictly so called, from the general uniformity of their contents, and from the fact, of their frequently receiving a part of injections thrown into arteries. But the following reasons may be given for thinking, that the whole of this system of vessels is engaged in the work of absorption.

1. The whole of these vessels are constructed exactly alike, and they lead to the same termination; and the absorbing power of the lacteals is undoubted.

2. Although these vessels have been often filled by matters injected into arteries, yet, after the most minute

and successful injections made by Mascagni with size and vermilion, and where no rupture of vessels could be detected, it was found that the matter existing in these vessels was only the colourless size, which had transuded on the surface of membranes, and into the cellular texture; and *this colourless size was found in these vessels only*, all vessels which contained coloured matter being traced to arteries and veins; so that the evidence of these injections favours the belief that the lymphatic vessels are not continuous with arteries, but may be filled by any matters that are effused from arteries.

3. The well known morbid phenomenon, of those lymphatic glands very frequently becoming inflamed which lie in the course of the lymphatic vessels leading from ulcerating surfaces (where it is certain that absorption is going on, and where noxious substances are often absorbed from without) strongly indicates that it is through these vessels, at least in part, that this process is carried on.

4. In some cases, a striking correspondence has been observed by Mascagni and others, after death, between the contents of the lymphatic vessels of parts of the body and various morbid effusions or secretions existing at those parts.*

The absence of any peculiar matters from the *larger* branches of the lymphatics, remarked by Andral and others, in many subjects where extensive suppurations or other effusions had existed, is not decisive evidence against this doctrine; particularly as it is known that the contents of these vessels are often moved forwards, after most of the functions of life have ceased.

But we have now satisfactory proofs that the function

* See particularly Mascagni, Vasor. Lymphat. Historia, p. 20. The most important cases recorded by him are not noticed in the commentary on this passage by Magendie.

of Absorption is carried on likewise by Veins, and to a much greater extent than the small number of vessels having the character of lymphatics, which have ever been satisfactorily traced into the smaller veins, can explain.

The experiments of Hunter, made by exposing and isolating small portions of the intestines of living animals, filling them with different fluids, chiefly milk and a solution of indigo, and then examining the contents of the lacteals, and of the veins leading from these, may be allowed to prove two points: 1*st*, That absorption, at least of milk, and probably of other fluids, different from chyle, took place, in his trials, by the lacteals; 2*dly*, That no absorption could be ascertained, in his trials, to have taken place by the veins.

The first of these, which is a positive observation, although opposed to the results obtained by Magendie and others, agrees with the results of many other experiments, by Lister, Haller, Blumenbach, Tiedemann and Gmelin, Lawrence and Coats, and Fodera, in which it appeared that a certain portion of different fluids, introduced into the intestines, was taken up by the lacteals; and the possibility of their absorbing fluids different from chyle may, therefore, be held to be decided. But the second observation of Mr Hunter, which is a negative one, is quite an insufficient ground for the general conclusion, that veins do not absorb; and the reality of venous absorption is now put beyond all doubt, by the positive observation of many physiologists, particularly by the following.

1. The experiments of Sir E. Home and Mr Brodie* prove, that when the great lymphatic trunks are tied in warm-blooded animals, substances injected into the stomach, nevertheless quickly find their way into the circulation, and may be detected in the urine.

* Phil. Trans. 1808.

2. Experiments made by Magendie, Flandrin, Tiedemann, and Gmelin, and others, prove that odoriferous substances, known by their smell, and saline substances, indicated by their tests, after being taken into the stomach, are detected in the veins on the mesentery, both larger and smaller, and in the vena portæ, much more than in the lacteals and thoracic duct.

3. Experiments made by Magendie, prove that a poison introduced into an isolated portion of an intestine, communicating with the rest of the body only by an artery and vein, or into the cellular texture of a similarly isolated limb acts in the usual way, and nearly in the usual time, when the circulation is free.

4. In experiments made by Segalas, it appeared that a poison introduced into a portion of intestine between two ligatures, failed of effect as long as the artery and vein leading to that portion were tied, or the venous blood allowed to escape by a wound in the vein, although the lacteals and other textures were uninjured ; but took effect as soon as the circulation was set free, and the venous blood allowed to return to the heart.*

5. In experiments made by Professor Mayer, it appeared that saline substances introduced in small quantity into the bronchiæ of animals, found their way very quickly into the blood, although the thoracic duct was tied ; and were detected in the left side of the heart much sooner than in the right side.†

6. In experiments by Fodera,‡ it appeared that two saline solutions, applied to the inner and outer membrane of an isolated portion of intestine in a living animal, *were*

* Journal de Physiologie, 1822.

† Bibliotheque Universelle, Jan. 1818.

‡ Recherches Experimentales sur l'Absorption et l'Exhalation.

united in the small veins leading directly from that portion of intestine.

7. In experiments by Magendie, it appeared that a poison applied to an isolated vein, with all precautions to avoid contact with other textures, or even to an isolated artery, gradually transuded into the interior of the vessel, and then produced its usual effects.

8. In experiments by Dr Handyside,* it appeared that saline matters laid on the surface of the true skin, or of granulating sores, or of the mucous membrane of the primæ viæ, appeared exclusively in the veins.

In cases of disease where large deposits of morbid matter have taken place within a short time,—in cases of Suppuration, of Fungus Hæmatodes, and of Melanosis, the veins of the affected parts have been found loaded with the morbid matter, more generally than the absorbents; which has been also regarded as a proof of venous absorption; but it will appear from facts to be afterwards stated, that the most probable explanation of this appearance is different.

It would appear, however, from what has been said, that the veins are concerned in the function of absorption in all the following ways:—1. They themselves absorb, chiefly by their smallest branches, at least fluid matters. 2. The contents of the lacteals and lymphatics are probably partially intermixed with those of the veins in lymphatic glands. 3. Some of the smaller lymphatic trunks terminate in veins. 4. The largest lymphatic trunks terminate in the great veins of the neck.

From the inner membrane of the intestines, it would seem, from the observations of many experimenters, that the absorption of thin fluids is chiefly by veins, and that of the chyle, which is a thicker fluid, by the lacteals

* Report of British Association at Dublin, vol. v.

only. And perhaps in all parts the lymphatic vessels, being of larger calibre than the capillaries, are intended simply for the absorption of substances consisting of larger particles than those, which can easily enter the latter vessels.

Dr Handyside, from observing that foreign saline matters seemed to be taken up, in the living body, by veins only, was led to conjecture that the office of the lymphatic vessels may be confined to the interstitial absorption of portions of the solid textures. These negative observations do not entitle us to set aside the positive observations quoted above, as to the absorption by the lacteals of other matters besides chyle; and we do not see how the known absorption of the substance of the brain, can be effected by any lymphatics yet demonstrated. But these observations may be connected with the statement of Dr Prout, that the process of absorption of solid textures all over the body, is probably preceded by a solution or assimilation of these by means of a fluid (probably an acid fluid) thrown out by the bloodvessels; a process similar to digestion being, as he thinks, not confined to the primæ viæ. If this be so, it becomes probable that their absorption will be by the same system of vessels as the lacteals; and this speculation appears farther important, as furnishing a probable explanation, both of the general uniformity of the contents of the lymphatics (stated by Magendie and others as evidence against their absorbing power), and also of the innocence of excretions reabsorbed into the system from their outlets, as compared with excretions retained in the blood.

Two facts of much importance may be stated here, as natural consequences of the principle of absorption, in most parts, taking place chiefly by transudation into the

* See p. 101.

interior of vessels, in which a current of blood is continually flowing.

1. That the absorption is much diminished by unusual fulness of the sanguiferous vessels, and increased by their inanition, as appeared particularly in experiments of Magendie, where the effects of poisons introduced into cavities of the body were observed, first after an artificial plethora had been induced by injections of water into the vessels, and then after the vessels had been partially drained of their blood, and found to be much retarded in the former case, and accelerated in the latter.

2. That absorption from any surface of the body is much diminished, or suspended, by greatly diminishing the pressure or the atmosphere on the part ; as is shewn by the actions of a cupping-glass in many experiments of Sir D. Barry and others, preventing the absorption and injurious action of poisons.

II. That absorption of the fluids of the body is continually going on, is evident from familiar facts ;—as to the contents of the Alimentary Canal, from the disproportion between the ingesta and egesta ;—as to the Fat, from its diminution in consequence of fasting ; as to the Bile and Urine, from their higher colour and greater density when they are long retained ;—as to the contents of the Thorax and Abdomen, from the rapid disappearance of any fluid introduced there artificially, &c.

That a continued Absorption of the solids of the body likewise takes place, is concluded chiefly from the following considerations.

1. The same kind, and nearly an equal amount, of supplies from without, go to the blood during the adult state, and when the solids are apparently stationary in bulk, as during the period of the most rapid growth.

2. The penetration of the solid textures by arterial blood is necessary to preserve them from putrefaction, and it seems probable that this preservation is effected by a perpetual change of their particles.

3. In various circumstances, both of health and disease, absorption of animal solids is easily caused, and shews itself unequivocally; *e. g.* in the muscles in consequence of rest;—in all textures, and especially in the Bones, in the decline of life;—in the Thymus Gland after birth;—in the Uterus after delivery; in the gradual alteration of the form of several bones and other organs, both during their growth, and in the subsequent progress of life; in the gradual diminution of the size of various organs, by *interstitial absorption*, in consequence of fasting, and of different diseases;—and of almost all organs, by *progressive absorption*, when they are subjected to unusual pressure from tumours or abscesses;—and in the process of Ulceration. In all these cases, as the vascular organization of the parts, in which the increased absorption is going on, undergoes no material change, it cannot be supposed that the vessels have assumed an unwonted office.

There is, however, great variety as to the facility and rapidity of absorption in different textures. The permanence of the marks on the surface of the body produced by gunpowder, and by tatooing, and the long duration of the colour produced by the full internal use of nitrate of silver, sufficiently indicate that the renewal of the particles of the true skin is a very slow process. But the facts stated leave no room for doubt, that those of the animal solids which are provided with vessels, and are dependent for their properties on the constant flow of blood through these vessels, are subject to a continual although slow process of absorption and renewal of their particles;

and therefore, that we ought to regard the function of Absorption as serving two important purposes in the animal economy, viz., the reception of foreign matter to be added to the nourishing fluid, and the continual removal of existing parts of the body (solid and fluid) and its mixture with that fluid, probably with a view to excretion.

It is important to remark, as to the first of these, the careful provision made by nature for the very gradual and intimate intermixture of any foreign substances, by this function of absorption, with the circulating blood; and for the rejection of part of these foreign substances from the blood, before they are applied to any useful purpose; *e. g.* the division of alimentary substances in the primæ viæ into those taken up by the veins and lacteals; and the passage of the first through the capillaries of the liver, and of the last through the mesenteric glands and thoracic duct (where they meet with highly animalized fluids), and of both through the capillaries of the lungs, before they reach the arteries. The lymphatic glands, in animals that possess them, the plexuses of lymphatics, (communicating with veins) which seem to supply their place in others, and the passage of venous blood (mixed with the contents of lymphatics) through the kidneys in many animals, seem destined for the same purpose. And as there is so much provision for the gradual elaboration of the blood before it enters the arteries, we can the more readily understand, that the evolution of so many different substances from the capillary arteries may be so simple a process as observation seems to indicate, or, according to the expression of Du Trochet, may be merely a Chemical Filtration.

CHAPTER VIII.

ON THE PROPERTIES OF THE TEXTURES AND SECRETIONS FORMED FROM THE BLOOD IN THE LIVING BODY.

The different Textures and Secretions which are formed from the blood, are the materials which are variously combined in the constitution of the different sets of organs, the functions of which are considered in the other departments of Physiology; and a knowledge of the *general anatomy* of these is essential to a right understanding of the uses to which they are applied. We introduce here, therefore, a short summary, in regard to each texture, *first*, of its merely physical properties, the purposes these serve, and its distribution over the body for these purposes; *secondly*, of its chemical properties and composition; and, *thirdly*, of the vital phenomena it exhibits, and the peculiarities of any secretions that may be formed in it.

Almost all the solid textures have appeared to several observers, under the microscope, to consist in a great measure of minute globules, nearly of the same size with those existing in the blood. But the investigations of Mr Brown, Dr Hodgkin, and others, render it probable that that appearance is deceptive.

The knowledge of the chemical composition of the different textures, and of the fluids formed in them, gives at present but little assistance, either to their Physiology or Pathology; but will no doubt assume a greater importance, when we shall have more precise ideas as to the mo-

difications which chemical principles undergo in living bodies.

The strictly vital phenomena presented by most of the textures, are nearly confined to the vascular parts included within them, or affect only the blood in those vessels; but the most important vital properties of some of the textures, particularly the muscular and the nervous, reside evidently in parts exterior to the vessels.

We omit, for the present, all mention of the sensibility of the different textures; that being in fact a part of the Physiology of the Nervous System.

We consider here, first, those textures which have originally a cellular structure, and may be made to shew somewhat of that structure by maceration in water; and afterwards those which shew a fibrous, but not a cellular structure, which are two only, the muscular and nervous.

But looking to the uses of the different textures in the living body, we may make a more strictly physiological division of them as follows:

I. There are some which are useful only by their *physical* qualities;—forming thereby the framework of the living machine, but not directly concerned, either in producing its vital actions, or in supplying its moving power, or repairing its waste. Here we may include Bone, Cartilage, Fibrous texture, Synovial, Cellular and Serous membranes, with the fluids formed by them.

II. There are many other solids and fluids in the living body, which fulfil their purpose by a strictly *vital* action, and these may be arranged as follows:—

1. There are some which are concerned directly or indirectly in maintaining the proper quantity and quality of the blood, and in so doing connect the organic life of animals with the external world;—the skin and mucous membranes and their secretions, which give the necessary

protection against the too sudden application of foreign matters; the different glandular structures and secretions connected with the alimentary canal, which are employed in the assimilation of aliments; and the different organs of excretion, by which the residue of the vital operations is continually expelled, and the blood purified. It is to be observed that several organs and textures, as the skin, the lungs, the liver, and the mucous membrane of the bowels, are of use in more than one of the ways now mentioned, but the principle of the arrangement is not thereby affected.

2. There are two textures only which are directly concerned in virtue of their truly vital powers, in the performance of the motions of living solids, peculiar to animals, viz., the Nervous and Muscular textures.

3. There is only one texture directly concerned in the strictly mental acts and operations which appear obviously to be the main object of nature in the construction of living animals, viz. the nervous system, and especially its central masses; but in connection with it there are several textures peculiar to the organs of sense.

I. Of Bone.

This, the hardest and densest of the animal solids in man, as in other vertebrated animals, gives the general form to the body, and the requisite strength and support to many of its parts. It gives protection to the most important viscera, and firm attachments to most of the muscles, and to ligaments, tendons, and fasciæ; and the articulations of the different bones are essential to most of the muscular movements.

All the bones are composed of laminæ, so arranged as to form cells, which in the long bones have the form of minute longitudinal canals. All have a firm investing

membrane externally, and a more delicate membrane lining the cavities in their interior, in which the medulla is lodged. There are important differences as to the arrangement of the cellular structure in different bones. The external parts are the most compact; in the short and flat bones, the internal cellular structure is pretty uniform; whereas the broad extremities of the long bones of the limbs are composed of a spongy texture throughout, and their narrower shafts have a thicker compact structure externally, and a long cavity in their interior. By these arrangements these bones have sufficient strength, combined with lightness; their articulating ends have sufficient breadth; and they give both sufficient room for the fleshy bellies of the muscles, and advantageous attachments for their tendinous extremities.

The bones consist of earthy and animal matter, which are intimately incorporated, even in the minutest particle of their substance.* The earthy matter, in the adult state, constitutes nearly two-thirds of their weight. It consists almost entirely of Phosphate with a little Carbonate of Lime. These may be freed from the animal matter by burning bone, or they may be dissolved from it by diluted muriatic acid, and successively precipitated from the solution Ammonia, and Carbonate of Ammonia.

When bone has been deprived of all its animal matter by the action of fire, it retains its hardness, but has become brittle and inelastic; when all its earthy matter has been extracted by acid, it retains its form, but has become soft and flexible.

Two animal principles are contained in, or may be easily procured from bone,—Gelatin and solid Albumen. The gelatin is obtained by the long continued action

* See Gordon's System of Anatomy, p. 253, and Craigie's General and Pathological Anatomy, p. 531.

either of diluted muriatic acid or of boiling water; and by the continued application of these agents, particularly by water heated under pressure to above 212°, its quantity is so much increased, that it is probably in part formed by the process. The albuminous contents of bone remain after both these processes.

The Gelatin which is procured from bones and from various other animal textures, by these means, is distinctly characterized by its ready solubility in hot water, and its forming a tremulous mass when cooled, by its solubility in diluted mineral acids, by combining with caustic alkalies, but not forming a compound like soap; by its being convertible, by the action of sulphuric acid, into a saccharine matter; by the copious precipitate it forms with the vegetable astringent principle called Tannin; and also, by being more putrescible than the other animal principles already mentioned. It differs from the others chiefly in containing more Oxygen, and less Carbon, its analysis being,

Carbon.	Hydrogen.	Oxygen.	Azote.
47.8	7.9	27.2	16.9

These differences may give us a general idea of the manner in which this substance may be formed in the living body, from the albuminous contents of the blood.

The effects of injury, and particularly of fracture of bones, the effects of pressure, from whatever cause, exerted on them, and the effects of various diseases, sufficiently indicate, that the vital processes of nutrition and absorption are performed in this texture with activity; and may go on to a greater extent than in almost any other texture, although they take place more slowly than in many of the soft textures.

But the vessels that can be traced into the substance of bones are minute; and their nutrition is very dependent on the vascular membranes which invest them in-

ternally and externally, and on which their vessels ramify, until they are much reduced in size. Hence the destruction of either of these membranes causes always the death, at least of the adjoining portions of bone ; and in the reparation of bone the adjoining soft textures are always, although not exclusively, employed.

The nutrition of bone takes place, partly no doubt in its substance, but chiefly beneath the periosteum, on its surface. Experiment has shewn (although in opposition to Scarpa and others) that a portion of periosteum, from the interior of which all the bone has been removed, with firm fresh bone on its inner surface ; and in the case of fracture, it would even appear that a part of the lymph, which is converted into bone, is thrown out, in the first instance, by the vessels of other soft textures, exterior to the periosteum.*

The absorption of bone in the living body, is so easily produced by pressure, that bones are obviously modelled, in a great measure, by the pressure even of soft living parts (*e. g.* arteries) within or beneath them ; and it would seem, particularly from the medullary cavities within the bones gradually enlarging after their growth is completed, that the presence of the medulla determines absorption to go on habitually from their interior, more than from their surface.

The red colour which is given to bones, by mixing madder with the food of animals, particularly when young,—and the rapid disappearance of that colour, especially from their outer part, after the use of the madder is discontinued,—are proofs of their vascularity, and of the ready escape of substances from, and subsequent re-entrance into, their bloodvessels ; and farther indicate that these

* Syme in Trans. of Royal Society of Edin. 1837. Dupuytren and Cruveilhier. Dic. des Sciences Medicales, Art. Ossification.

changes take place most readily on their outer surface. But these experiments do not prove, that the earthy matter of the bones is deposited and reabsorbed with such rapidity as the colouring matter of the madder; because the union of this with the earthy matter of the bones when it is deposited, and its subsequent solution in the serum when it is absorbed, appear to be simply chemical phenomena;* and in advanced life particularly, the renewal of the bony texture, in the healthy state, seems to be a very slow process.

The Medulla, which is contained in the cavities within the bones, and confined by laminæ of the internal membrane passing across these cavities, does not materially differ from fat or other animal oils. Like the others, it has been found to consist of two oils, one fluid and the other solid at ordinary temperatures, which are mechanically separable from each other, and to which the names of Oleine and Stearine have been given. It has no connexion with the synovia of the joints; nor is its use understood, except in so far as it contributes to the combination of strength and lightness in the bones, and may assist in determining their forms.

The Teeth, in the adult state, divided by their form and position into four incisores, two cuspidatæ, four bicuspides, and six molares in each jaw, are distinguished from other bones by their position—being implanted in the maxillary bones, and invested only as far as the neck by periosteum—by the cavities within them, which contain a vascular pulp, and communicate with the rest of the body by the apertures at the extremities of the fangs;—and by the peculiarity of their composition, the bone which forms the greater part of each tooth containing

* Gibson, Manchester Memoirs, New Series, vol. i.

above 70 per cent. of earthy matter, which is more than any other bones contain; and the enamel, which coats the crown of the teeth, containing, according to Berzelius, not less than 98 per cent. of earthy matter, including above three per cent. of fluate of lime.

As the bony matter of the teeth in ordinary cases, not only shews no vessels after the finest injection, but undergoes, in the adult state, no change of size or form by any vital process,—is never repaired after injury,—is unaffected by diseases of the other bones,—and appears subject to no alteration except simple decomposition,—this texture, or at least as much of it as exists in the crown of the teeth, cannot be regarded as possessed of vitality, after the period of its growth is over; but there may be a few cases in which strictly vital phenomena are exhibited in it at a later period.*

II. Of Cartilage.

This texture is found in those parts of the body in which there is occasion for the physical qualities of strength and firmness, combined with more or less of flexibility, and with elasticity, which are its characteristic properties. From these qualities, and from its smooth surface, arise its great importance and utility in the formation of the joints, and in the junctions of various bones,—in the composition of the spine,—in the nostrils, larynx, and trachea,—external ear, &c.; but in these different situations it is found under considerable variety of density and flexibility, and, in some parts, approaching to the flexibility and toughness of tendinous substance, has received the name of Fibro-cartilage. The structure of the harder cartilages, as those at the ends of bones, is almost perfectly homogeneous.

* See Bell on the Teeth.

Its chemical composition appears to be nearly identical with that of the animal matter of bones. By long continued boiling in water, under pressure, it may be almost entirely converted into a gelatinous solution, but the ordinary operation of boiling leaves a considerable albuminous residue.

Cartilage is invested with a membrane nearly resembling the periosteum, but no vessels can be traced into its substance, excepting where it is about to undergo conversion into bone. That it possesses vessels, however, has been generally inferred from various changes which it occasionally undergoes in the progress of life, and still more in disease; especially from its being sometimes partially absorbed, and sometimes altered in structure, without alteration of the adjoining bones; but it is a curious and important observation of Mr Key, in accordance with facts formerly stated, that the agent in such absorption of cartilage, appears often to be an inflamed and vascular process of membrane lying in contact with it, not continuous with it, but *attracting* its particles.*

As it contains little or no earthy matter, cartilage, in the dead body, resists decomposition much less than bone does; but, on the other hand, as it is so much less vascular than bone, it undergoes changes dependent on vital actions much more slowly, and offers much more resistance, in the living body, to the processes of progressive or ulcerative absorption.

III. Of Tendinous or Fibrous Substance.

This substance composes not only the tendons, but the ligaments and certain membranes, viz. the Periosteum, Dura Mater, Tunica sclerotica of the eye, and Aponeu-

* London Medico-Chir. Trans., vol. xviii.

roses or Fasciæ. All these consist of delicate white fibres, of a shining or silvery appearance, differently disposed. This texture possesses more tenacity or toughness than any other in the body: and, with the exception of the periosteum and dura mater (the importance of which to the nourishment of bones has been already stated), it appears to be useful in the animal economy only by this mechanical property of toughness, which renders it a sufficient attachment for the origin of certain muscles; the best medium of connexion by which muscles can be attached to bones, and bones to each other; and the firmest bond by which the movements of muscles, tendons, or other parts, can be confined to the proper places and directions. That it may answer these purposes, it has, in many parts of the body, firm connexions with bones. Most parts formed of this substance resist the action of boiling water more than many other textures do; but gelatin may be obtained from them all, and the tendons are almost entirely resolvable into it. The portion that resists the action of boiling water, does not seem to differ essentially from solid albumen.

The membranes of this class are fully provided with vessels, and give frequent evidence of alterations of the vital process of nutrition; but the vital actions of ligaments, and more especially of tendons, are slow and feeble, and all parts formed of this texture exhibit in disease, and particularly in inflammation, less violent and rapid changes than other membranous parts. Being little liable to absorption, they often set bounds to ulceration, or other diseased actions; and by their physical qualities, they often compress inflamed parts, and confine, or alter the direction of, morbid effusions. Hence the practical importance of acquaintance with their anatomical disposition in the body.

IV. Of Cellular and Adipose Substance.

The first of these names is given to the soft filamentous substance very generally extended over the body, which connects together the various soft parts of the animal frame, and fills up all interstices; and the slender laminæ of which are so interwoven with each other, that when raised or distended, they appear to form numerous irregular cells communicating freely with each other. It varies much in density in the various parts, where it is interposed between the more determinate forms of other textures, *e. g.* beneath the integuments, around and between the fasciculi of muscular fibres, between membranes, around vessels, and in the substance of glands; but gives a free passage, in almost all parts, either to liquids or air. It is everywhere lubricated by a little serous fluid; and its degree of tenacity, with its softness, flexibility, and moisture, make it the best cement for holding together such parts of the body as do not require, or would be injured by, firm constraint.

This texture yields gelatin abundantly, though not readily, to boiling water. It is not only penetrated by numerous larger bloodvessels, but shews, on injection, more numerous capillary bloodvessels and absorbents, than any of those textures in which no fluids are formed.

The quantity of serous fluid exhaled into the general cellular texture, in the healthy state, is very small. But in many parts of the body, cellular membrane, of a more determinate form, encloses within it a quantity of animal oil, and this has the name of Adipose Texture. This appears to be in a fluid or semi-fluid state, in the living body, but is retained in the cells, even in the dead body,

and when rendered quite fluid by heating, until these are ruptured.*

This adipose texture is found in the greatest quantity beneath the true skin, about the kidneys, and in the mesentery and omentum, in the orbits, within certain glands, about the heart, &c. There is little or none beneath the integuments of the head, in the male organs of generation, about the joints, or in the substance of most of the viscera. The composition of the animal fat has been thus stated ;

Carbon.	Hydrogen.	Oxygen.
69	21.34	9.66

This and others of the animal oils, are easily distinguished by these marks, that they melt at about 96°, are very inflammable, are insoluble in water or alcohol, and form soap with the alkalies.

This texture is useful in those interstitial spaces in the body where a certain quantity of soft but tenacious substance is required, to obviate pressure, or preserve symmetry. The subcutaneous fat is manifestly useful in preserving the heat of the body. It is obvious likewise, from the growth of this texture usually going on long after all other healthy growth in the body is over, and sometimes, in healthy and well-fed persons, to a late period of life, that it serves as a receptacle for superfluous nutritious matter ; but we know nothing of the principle which determines the formation of this rather than any other animal product, in these circumstances. There is reason to think, that fat deposited in, and again absorbed from, the cellular texture, is the cause of the unusual oily appearance occasionally seen in the serum of the blood ; but it is very doubtful whether the fat that has been de-

* Beclard, Anat. Gen. p. 161.

posited from the blood, and again taken into the circulation, can be applied to the nourishment of any other parts.

The cellular and adipose textures are very often the seat of rapidly increased deposition from the bloodvessels, as in cases of Anasarca, local or general, in persons previously healthy, and in the rapid increase of bulk of persons convalescent from acute diseases, or recovering from the effects of labour and fasting. They are frequently the seat of active absorption, as is seen in the rapid disappearance of anasarcous effusions, or of mild fluids injected into healthy cellular substance, and in the speedy wasting of the body from fasting, fatigue, or acute disease. They are also the frequent seat of inflammation and other local diseases, in the course of which both deposition and absorption are greatly increased and altered. These facts leave no room for doubt, that in the natural state, these processes continually take place, and balance each other, in the fluid contents of these textures. The adipose texture can itself only be formed, in the healthy state, in certain parts of the system; but the formation of a dense cellular substance from the blood appears to take place readily, after injuries and inflammation, in almost all parts of the body; and even to be a general preliminary to the original formation, and to the reparation, of other textures.

V. Of Serous Membrane.

This is the thin pellucid texture that lines the parietes of the great shut cavities of the body, and is reflected to form the covering of the viscera. Its free surface, towards these cavities, is perfectly smooth and moist; its attached surface graduates insensibly into adjacent cellular membrane, from which it appears to differ only in

greater condensation. It shews, in most parts of the body, no fibrous structure; but in some parts, as the Pericardium and Tunica Albuginea Testis, it approaches to the nature of fibrous membrane; and in general, is of considerable strength, and gives a firm, smooth covering to parts that are always in contact, but destined to separate movements, in which they slide on one another; admitting likewise of much greater distention than the fibrous membranes do.

In chemical composition these membranes do not appear to differ from cellular texture, but they yield gelatin sparingly and slowly to boiling water, and they resist putrefaction long. They shew hardly any bloodvessels in the living state, but very numerous capillaries and absorbents on injection; many of which, however, are really lodged in the cellular substance just beneath them.

Some physiologists attribute to these membranes, and even to cellular textures, a degree of the vital property of Tonicity, but its existence in them has not been clearly ascertained. Their chief vital function is the formation of the small quantity of fluid which lubricates them, and which contains the same animal and saline matters as the serum of the blood; but the animal matter in proportions always less than in that fluid, and various in the different cavities. The proportion of albumen in the serous effusion on the pia mater, and in the ventricles of the brain, is very small.

That a continued exhalation of this fluid on the serous membranes is always going on, may be concluded from the rapidity with which increased effusion sometimes takes place in disease, or may be produced, in experiments on animals, by injecting water into the arteries;* and that a continued absorption is going on, may be concluded

* Magendie, Precis Elementaire.

from the rapid disappearance of fluid effusions there in some cases of disease; and especially from the uniformly rapid disappearance of fluids that may be placed in contact with serous membranes in living animals, as in experiments by Hunter, Magendie, and many others.

These membranes are likewise easily increased in thickness, and altered in composition, by disease, and adventitious organized structures are often formed on them, by inflammation and otherwise; but they are not nearly so liable to absorption, either from pressure, or in consequence of disease, as some other soft textures; and these peculiarities of their vital properties are of great importance in Pathology.

The Synovial membranes, which line the inside of the capsular ligaments of joints, and are reflected in a very attenuated form over the articulating cartilages,—and similar membranes which line the sheaths of tendons, where these pass over bone or cartilage,—resemble the serous membranes in most respects, and have the same use in regard to the firm textures which play on one another in these parts, as the serous membranes have, in regard to the motions of the viscera. But they are less flexible, in the natural state less vascular, and form a more viscid fluid, containing not merely the constituents of the serum, but another animal substance which has been likened to mucilage. The alterations of their vital properties in disease are likewise less rapid than those of serous membranes; but the changes, or even destruction, of their substance, in some instances go to a greater length.

Of those textures which fulfil their object in the living body by their vital properties and action, the first mentioned are those which give protection against the effects

which would be otherwise injurious, of foreign matters introduced into the system, or noxious matters about to be expelled from it. These are the skin and the mucous membranes. We delay the consideration of the functions of the skin, because it is also an important organ of excretion, and therefore we go on to treat,

VI. Of Mucous Membrane.

This is the texture which lines all those cavities within the body which open on its external surface; it is therefore every where continuous with the skin, but nowhere, except at the ends of the Fallopian tubes in the female, continuous with any other membrane. It varies very much in thickness, and considerably in other respects, in the different parts of the air passages, alimentary canal, and organs of urine and generation; but in all parts is distinguished by the fluid effused on it being more viscid and less translucent than serum. In most parts it is thicker, and in all parts of softer and more spongy consistence, than serous membrane, and its free surface is more completely supplied with capillary bloodvessels and absorbents, and is beset with numerous very minute prominences or *villi*. The whole membrane is in many places longer than the surface to which it is attached, and is therefore thrown into folds, increasing its surface. In most parts of the body it is studded by openings, leading to minute glands and follicles, which effuse a mucus on its surface similar to that which it secretes. This kind of membrane likewise receives the outlets, and lines the interior, of the ducts of all the true glands in the interior of the body.

This texture is more acted on by cold water, and less by boiling water, than any other of the animal membranes, and is more rapidly decomposed after death than any other. The fluid found in it contains not only the animal and saline constituents of the serum, with a very small proportion of albumen, but also a quantity (according to Berzelius above 5 per cent.) of a peculiar animal matter, to which it owes its viscidity; which is obtained by filtering and drying, and varies somewhat in the different mucous membranes, but is distinguished by being easily diffused through cold water, little affected by boiling water, and not precipitated by the tests, either of albumen or gelatin, nor soluble in alcohol.

The surface of these membranes is the scene of continued secretion, which is obvious to the senses in various parts; and of continued absorption, which is made manifest by the change in quantity and quality, which is speedily effected in any substances placed in contact with them. There is also, in the healthy state, very great occasional variation in the quantity of blood sent to them, and in the quantity of secretion formed on them; and, in the case of the stomach particularly, in the quality of that secretion. The causes and purposes of these variations will be considered afterwards.

The characteristic qualities, and especially the vital properties, of all the mucous membranes, appear to be chiefly connected with the circumstance of their forming the surface over which all foreign substances taken into the body, and formations in the body destined to excretion, must necessarily pass. By these, the vital actions of secretion and absorption going on in them are continually stimulated; the increased secretion of mucus, occasioned by any unusual irritation, appears to answer the same purpose, of defending the membrane, as the per-

manent covering of the cuticle does to the surface of the body, which is more permanently subjected to such foreign irritation ; and such is the adaptation of the vitality of these membranes to the action thus exerted on them, that the same substances which only excite them to healthy and salutary action, no sooner touch the surface of serous or synovial membranes, or even of cellular texture, than they excite violent inflammation.

The activity of the vital actions that take place in these membranes, is farther attested by the frequency of increase and alteration, both of their secretion and of their nutrition in disease, and by the peculiar liability of those of the alimentary canal, at least, to ulcerative absorption.

The most important discovery lately made as to mucous membranes, is that of Purkinje, who detected on certain of them,—those in the air-passages and the genitals,—currents of the fluids lining them, following determinate directions, persisting only for a short time after death or removal from a living body, and accompanied by a vibratory movement of minute ciliæ, which invest the surfaces where they are seen. It has been concluded (perhaps too hastily) that these currents are entirely owing to the impulse given by the motion of the ciliæ to the fluid in contact with them. The probable use of the currents in those parts will appear under the heads of Respiration and Generation.*

VII. Of Glands and their Secretions.

Confining the term Gland to those organs of the body which separate peculiar fluids from the blood and discharge

* See Sharpey, Art. Ciliæ in Cyclopædia of Anatomy and Physiology.

them by ducts, we find much variety as to the disposition of these ducts or their branches, as well as in the purpose to which the fluids formed are applied. To avoid repetition, some general observations may be made on all glands, before treating of their purposes.

The simplest kind of gland is a short membranous canal, opening on the surface of a mucous membrane, or of the skin,—such as the lacunæ of the urethra, and the sebaceous, Meibomian, and ceruminous glands or follicles. Even by so simple an apparatus, very various substances are formed.

Most of the glands that pour out mucus on the mucous membranes, consist of a pulpy vascular substance surrounding a little canal, and these are often set together in clusters, as in the Tonsils, glands of Peyer and Brunner, &c.

In all the larger glands, the excretory duct is formed by the union of smaller tubes within the substance; but in the arrangement of these smaller tubes there is much variety. The smallest divisions of the glands, which have the secreting power, or the *acini*, seem to be similar in structure to the mucous glands just mentioned. In the strictly conglomerate glands, as the salivary glands and pancreas, these acini are connected into lobules, and the lobules into lobes, by distinct layers of loose cellular substance; and each lobule has its own duct passing along its central part. In the liver and kidneys, there is no such internal division into lobules, the acini being connected uniformly with each other, by dense interstitial cellular texture throughout the secreting parts of these glands. A large portion of the substance of the kidneys (called the medullary or uriniferous, are distinguished from the cortical or truly secreting part), consists of the excretory tubes exclusively, set close together, and converging very

gradually to the papillæ, which pour the urine into the calices. The excretory ducts of the Mammæ are so coiled up in the substance of the nipples, as to require the erection or extension of these, before they give free exit to the milk. The seminiferous tubes, which terminate in the vasa deferentia, are distinguished by their very numerous contortions, first in the body of the Testis, and afterwards in the Epididymis.

All the excretory ducts have probably a certain amount of vital contractile power, though muscular fibres have been detected only in a few. In several cases, the fluids secreted are retained for a time in peculiar organs, before they are applied to the purpose to which they are ultimately destined. The tears formed in the lachrymal gland, are effused over the eye-ball, and absorbed into the lachrymal sac, before passing into the nostrils; the urine is lodged in the bladder long after its secretion is accomplished; the bile regurgitates in part into the gall-bladder; and perhaps the semen into the vesiculæ seminales.

All the glands are very fully furnished with bloodvessels and with absorbents; their arteries are stated to be of peculiar strength,* and are very minutely subdivided in their substance.

The supply of blood to all the glands, as to the mucous membranes, is also liable, in the healthy state, to great and sudden variations, from different causes, mental and physical. These are attended by great differences in the amount of the secretions formed there; and there is also great variety in the quantity and quality of the secretions in various diseased states. The nutrition of the glandular substance itself is, in some instances, subject to change in the progress of life, and in general is easily increased or perverted in disease. Absorption of the secreted mat-

* Wintringham.

ters takes place readily from the whole course of their outlets, as is obvious when the excretions of bile, urine, or milk, are unusually long retained, or their excretion obstructed ; and absorption of the substance of glands themselves is easily effected, apparently by pressure, in those cases where their ducts are long obstructed, or where preternatural deposits take place in their neighbourhood, or in their own interstitial cellular substance.

The numerous and elaborate investigations of the German anatomists, and particularly of Muller, made by different modes of injection, in all classes of animals, and especially at the period of the first development, and simplest structure of glands, have amply confirmed the statement of Mayo, that " a membrane on which many vessels ramify, seems all that is necessary to any kind of secretion ; and that the varieties of secreting organs are only contrivances for conveniently packing a large extent of such a surface in a small compass ;" and again, that the smallest divisions of all the glands, which have the secreting power, seem to be similar in structure to the mucous glands, *i. e.* to consist of a pulpy vascular substance surrounding a little membranous canal.* All these canals, in the case of most of the glands, appear to have been originally shoots from the excretory ducts, which are first formed in the fœtus ; the membrane lining them is always continuous with the mucous membrane lining the excretory ducts ; and whether these canals are straight or contorted, whether they are merely convoluted or subdivided, whether they are lessened or enlarged in calibre at their extremities (all which varieties are seen in the same

* " Gravissimæ secretiones in simplicissimis membranis parantur, ut succus gastricus in homine." (Muller.) " Tunica non ideo mucosa est, quia cryptas mucosas continet, imo potius cryptæ sunt mucosæ, quia ex tunica mucosa constant et efflorescunt." (Weber.)

glands in different animals), their terminations are always blind; they are always much larger, even at their extremities, than the bloodvessels which encompass them, though in general smaller in the higher animals, than the smallest lymphatics of the glands; and the secretion appears to go on over the whole extent of the membrane lining them, nor is it possible exactly to fix the limit where the mucous secretion of the excretory duct ends, and the proper secretion of each of its branches within the body of the gland begins. Thus the theory of Ruysch, of inosculation of the arteries entering the glands with the smallest excretory ducts, is satisfactorily refuted; and the theory of Malpighi, of secretion taking place into sacs or crypts within the glands, is so far modified, that the cavities into which the secretions transude, are found to be the whole extent of the branches of the ducts within the substance of the glands, not their extremities exclusively.

According to Kiernan, the smallest lobules set close together in the substance of the liver, have each a branch of the vena cava hepatica in its centre, around which a plexus of branches of the vena portæ, hepatic artery, and hepatic duct, ramify;* but in perfect accordance with Muller's description, he adds, that in all parts of this plexus, the blind extremities of the biliary ducts are found encompassed with numerous minute arteries and veins.† One part of each little lobule often appears paler than another, when there is less blood than usual in the gland, but there does not appear to be (as has been often supposed) any real distinction of the substance of the gland into grey and red matter.‡

* Phil. Trans. 1833, p. 710.

† Phil. Trans. 1833, p. 716, and Pl. xxiii. fig. 3.

‡ "Substantia canalium, seu tela glandulosa semper aut albida est aut albido-grisea, aut albido-lutea." (Muller, Op. Cit. lib. ix. § 29.); and Kiernan, l. c. p. 749.

In the secreting part of the kidneys, according to Muller, there are minute cells, distinct from the uriniferous tubes, which serve as receptacles of blood, and which are not seen in any other glands.*

The most important distinction of the secreted fluids, as regards physiology, is into the *recrementitious* and *excrementitious*; *i. e.* into those which are destined to some ulterior purpose in the animal economy, and those which are immediately excreted.

To the former class, besides the mucus of the mucous membranes and glands, have been referred the tears, which moisten the tunica conjunctiva of the eye-ball and membrane of the nostrils, and probably only important in preserving the transparency of the cornea; the cerumen, which is found in the meatus auditorius externus; the saliva, coming from the parotid, submaxillary, and sublingual glands, which is mixed with the food in the mouth; the secretion of the stomach, which is the chief agent in digestion; the pancreatic fluid and bile, which descend from the liver and pancreas, to be mixed with the aliment in the duodenum; and likewise the semen, and the fluid of the prostate gland, which is mixed with it at the origin of the urethra. These are stated by Berzelius to contain always the same saline ingredients as the serum of the blood, but little or no albumen,—and, instead of it, a single animal substance, varying of course in each instance; but subsequent observations do not entitle us to attribute so great simplicity to all these fluids. These secretions are generally, like the serum, slightly alkaline; but to this there is a remarkable exception in the secretion of the stomach, to be afterwards considered; and likewise, according to Tiedemann and Gmelin, in the se-

* Lib. x. § 48-12.

cretion of the pancreas. The chemical qualities and composition of the animal matters which they respectively contain, have been but imperfectly investigated, and cannot, as yet, be connected with their uses.

The most peculiar is that which is contained in the Bile, forms nearly 8 per cent. of it, and causes its bitter taste, and is most simply obtained from it, first by sulphuric acid, which precipitates it, and afterwards by baryta, which separates the acid. This has been likened to the vegetable resins, and stated to contain a small portion only of hydrogen, and no azote; its analysis being, according to Thomson,

Carbon.	Oxygen.	Hydrogen.
54.53	43.65	1.82

But whether there is in reality only a single animal principle in this fluid, or whether the picromel, cholesterine, and other substances which have been obtained from it by different processes, or separate spontaneously from it in biliary calculi, exist in it at all times, is doubtful.

In regard to the bile, there are two important physiological questions which may be stated here; 1st, Whether it is simply destined to excretion, or necessarily employed in digestion? 2d, Whether it is formed from the arterial or the venous blood of the liver?

1. It appears from various facts, that the peculiar animal matter at least of the bile, is destined to excretion only. This matter has never been found, in the healthy state, in the fluids absorbed from the intestines by the lacteals or veins; it is found in full quantity in the lower part of the intestines; it has been found to increase in quantity when the secretion of urine has been suppressed in animals by extirpation of the kidneys; when this secretion is repressed, the urine is increased and al-

tered ;* and it appears to be similar to a secretion in certain animals (of the class Mollusca), which is thrown out into the lower part of the intestine only, and immediately excreted.† The use of the other constituents of the bile, in digestion, will be considered afterwards.

2. Instances have undoubtedly happened in the human species, where the vena portæ had not entered the liver, and bile been nevertheless secreted. But, on the other hand, the experiments of Malpighi and of Simon, shew that tying the hepatic arteries in different warm-blooded animals, had little effect on the secretion of bile, but that it was suppressed by tying the vena portæ. The only other instance known of venous blood going to a gland, is the case of the numerous animals where large veins enter and are dispersed through the kidneys, and where any thing that escapes from them must be immediately excreted.‡

The most reasonable conclusion from these facts seems to be, that the liver can form bile both from arterial and venous blood, but that the latter is its chief source ; and that it should do so, is quite in accordance with what has been already stated as to the general nature of secretion, and particularly of excretion, and as to the pre-existence of the chief materials of bile, in small quantity, in all healthy blood.

The peculiar secretions of the Stomach, Pancreas, and Cœcum, and of the Mammæ, will be considered under the heads of Digestion and of Generation.

The Excretions from the living body, the continued discharge of which, according to the general law already

* Prevost and Dumas, in the Annales de Chimie, t. xxiii. ; and Simon, in the Annales des Sciences Naturelles, t. xiii. p. 110.

† Tiedemann and Gmelin, Recherches sur la Digestion.

‡ Jacobson, Edin. Med. and Surg. Journ. vol. xix.

stated as applicable to all vital action, is necessary to prevent its being poisoned by the fluids prepared within itself, are usually held to be four, the portion of the Bile already mentioned, the Urine, and the fluids thrown off at the Lungs and by the Skin.

It is to be observed, however, that portions of other secretions besides the Bile are habitually thrown off from the bowels, and in certain diseased states it is certain that much phosphate of lime is excreted, along with mucus, from the inner membrane of the intestines.

The most important fluid formed in glands, and destined merely to Excretion, is the Urine, which passes along a mucous membrane in its way from the kidneys, and is lodged for some time in the bladder, and is therefore mixed with a small proportion of mucus when passed; which mucus is somewhat heavier than the urine itself. The importance of this excretion appears from the great extent of the animal creation, in which a fluid of the same chemical character is found to be thrown off.

Urine has an average specific gravity of about 1024; 933 parts in 1000 of it are stated to be water; above 30 are the peculiar animal matter called Urea; and the remainder consists of salts in greater proportion and greater variety than in any other fluid of the body, with a little of another animal matter, probably similar to that in the serosity of the blood. The salts generally allowed to exist in it are, the Sulphates of Potass and Soda, Phosphates and Muriates of Soda and Ammonia, Phosphates of Lime and Magnesia, Lactic Acid, and Lithic Acid, or Super-Lithate of Ammonia. Minute quantities of Fluate of Lime and of Silica have been recognised in it; and Carbonic Acid has been obtained from it by the air-pump only. Of these, the acids are in excess, and hence the Lithic, being a weak acid, is frequently deposited, and is

apt to attach itself to and lead to decomposition of the mucus. But in other circumstances of the urine, and particularly when there is not the usual excess of acid, the phosphates are most easily deposited from it; and the Oxalic Acid, and other substances not detected in healthy urine, have been frequently found in gravelly deposits.

The Urea is dissolved from the Extract of urine, by alcohol, and obtained by evaporation, partly separated from the saline matters; it has a peculiar taste and smell, and is characterized by the bulky flaky compound it forms with nitric acid. By putrefaction, or by the heat of boiling water, as it exists in the urine, it is almost entirely converted into carbonate of ammonia; and it has been found to consist of

	Carbon.	Oxygen.	Hydrogen.	Azote.
	19·99	26·66	6.66	46.56
or	1	1	2	1 atoms.

containing, therefore, a much larger proportion of azote than any other animal principle.

The average quantity of urine evacuated in 24 hours may be about 40 ounces; but is liable to very great variations. The average quantity of solid matter that passes off by this excretion has been found to be not less than 15 drams in 24 hours;* and is apparently much less subject to variation, excepting in disease: the density of the urine, in the healthy state, being always diminished as its quantity is increased, and *vice versa*.

The appearance, already noticed, of urea in the blood, when the kidneys have been extirpated, or obstructed by disease, shews that the formation of this substance is at

* Dr Bostock (Medico-Chirur. Trans. vol. iii.) makes the quantity only 10 drams, but the experiments of Dr Henry (ditto, vol. ii.) shew, that even at the specific gravity of 1020, a pint of urine yields above 6 drams of solid extract, and therefore 40 ounces must yield above 15.

least so far advanced, before the blood, from which it is separated, enters the kidneys. And the conjecture of Berzelius, that it is furnished by the animal matter of the serosity of the blood, is rendered probable by two circumstances,—*first*, that the qualities of that portion of the blood (particularly its solubility both in water and alcohol) approach nearer to those of the urea than the qualities of the albuminous contents of the blood do; and, *secondly*, that after the extirpation of the kidneys, the animal matter of the serosity is first increased in quantity, and afterwards assumes the character of urea.*

It has also been supposed that the animal matter of the serosity, thus apparently convertible, at least in part, into urea, is not intended for nutrition, but is the product of that absorption from the component parts of the animal frame, which we saw reason to believe to be a necessary accompaniment of all vital action, and that it is destined to excretion only. And this opinion is supported by the phenomena of Diabetes, where there is ample evidence of very general absorption, from the wasting and dryness of the body, notwithstanding that more than the usual quantity of nourishment and drink is taken,—and in which the animal matter of the urine is enormously increased; and appears from the observations of Drs Bostock and Henry,† to retain, at least in some cases, the properties of urea for a time, and afterwards to assume, for the most part, the character of sugar: which conversion is probably in some way connected with the chemical relation, discovered by Dr Prout, between urea and sugar, viz. that the latter contains the same number of atoms of carbon and of oxygen as the former, with half as many atoms of hydrogen, and no azote.‡

* Prevost and Dumas, Annales de Chimie, t. xxiii.

† Medico-Chirurgical Trans. vol. iii. ‡ Ibid. vol. viii.

On the other hand, as a great increase in the quantity of urea and uric acid is found in urine voided soon after food has been taken, this may be thought to indicate that much of this excretion is rather the residue of the assimilation of recent aliment, than a product of absorption. And it seems now ascertained, that the commencement of the formation of sugar, in cases of Diabetes, is in the first stage of the assimilation of aliment, viz. in the stomach and bowels.*

Whatever be the source of the urea, which is separated from the blood at the kidneys, the necessity of this excretion appears distinctly from the fact, that when the blood is unusually loaded with this principle, it gradually acts as a poison on the system, and especially on the Nervous System; as has appeared uniformly when the kidneys of animals have been extirpated; and also, although in a less uniform manner, in the human body, when the secretion of urine has been either wholly suppressed, or more gradually and partially obstructed.

The facts now stated are already important in Pathology and in Practice; but the Physiology of Excretion, as well as of Secretion, will always be obscure and unsatisfactory, until we shall have some information as to the laws according to which chemical principles are modified in the economy of animals.

VIII. Of the Substance of the Lungs.

Although the mutual action that takes place between the air and the blood at the lungs, the manner in which it is effected, and its uses in the animal economy, de-

* See Baly's Muller, p. 588, and Maitland, Prize Thesis, Edin. 1838.

mand a separate consideration, yet some statements as to the texture of the lungs, and the nature and amount of the excretions from them, are more properly introduced here.

This texture, although varying much in density in different subjects, in consequence of the different quantities of blood it contains, is always, in the healthy state, of less specific gravity than water, because, from the time of birth, it always contains within it a large quantity of air, which is lodged in innumerable small cavities or air-cells, formed by little expansions of the ends of the ramifications of the bronchiæ which enter it. The texture may be said to be composed of mucous membrane, cellular substance, and serous membrane, with very numerous bloodvessels and absorbents. The membrane forming the cells, and on which the innumerable branches of the pulmonary artery and veins ramify, is continuous with that which lines the larger, and partly cartilaginous, branches of the bronchiæ, that enter the lungs from the trachea; and although of extreme tenuity, is believed to secrete a mucous fluid. The air-cells are bound together, and covered exteriorly by cellular substance, the cells of which, in the natural state, do not communicate with the bronchiæ. It is probable, though not completely ascertained, that the air-cells in the natural state do not communicate with each other, otherwise than by the branches of the bronchiæ, which open into them. The exterior cellular substance is bounded by the Pleura pulmonalis, which is everywhere in contact with, but in the natural state nowhere adherent to, the serous membrane that lines the inside of the parietes of the chest. The compound texture thus formed is endowed with a high degree of distensibility and elasticity, which are its most important physical qualities.

It is generally thought that this texture possesses no

vital power of contraction; but several phenomena, to be afterwards mentioned, render it probable that such a vital power does exist, to a certain degree, in it; or at least in the smallest branches of the bronchiæ that can be distinguished.

Air which has been in the cells of the lungs during life, is always found to be loaded in an unusual degree, with water and carbonic acid, much of which is evidently derived from the air-cells; and the mode of their formation will be considered under the head of Respiration. From some experiments by Dr Gordon, it would appear that no saline or animal matter can be detected in air that has been breathed, the water and carbonic acid being the only excretions, or exhalations, from the membrane of the cells, in the perfectly healthy state. But it is certain that many volatile matters, taken into the stomach, are excreted unchanged, or but little changed, along with the breath; and probably the body is thereby often saved from their injurious effects.

That absorption goes on with great facility and rapidity from the internal surface of the lungs may be concluded from experiments already mentioned, in which saline solutions, introduced into the bronchiæ, have been very soon thereafter detected in the blood, and likewise from the certainty and rapidity with which vapours, such as those of mercury and oil of turpentine, introduced into the lungs, come to produce the usual effects of those substances on the secretions. The effects of poisons introduced into the lungs, although rapid and decided, are not so unequivocal proofs of absorption.

The average loss of weight in a full grown man, in the day, which can be ascribed to the excretion at the lungs, appears, from experiments to be mentioned afterwards, to be not less than fifteen ounces; and the facts now stated

prove, that this must be only the excess of the excretion over the absorption at the lungs.

The black colour of portions of the lungs, and of the bronchial lymphatic glands connected with these, has been ascribed, with probability, to absorption of carbonaceous powder from the internal membrane.

The changes which take place in the form and size of a healthy lung, from the pressure of adjoining parts, and the expansion of one lung observed in cases where the other has been rendered unfit for its office, are sufficient proofs of the facility with which both absorption and nutrition of the pulmonary texture itself may be accomplished. The latter function is probably performed by the bronchial arteries only, and the last mentioned fact clearly shews, that it is very dependent on the vital actions going on at the extremities of the arteries in the lungs. There is good evidence, from the phenomena of different diseases, that the function of absorption in this texture is adequate, when other circumstances are favourable, to the removal, at least of serum and of blood, and perhaps of other matters morbidly effused into it.

IX.—Of the Skin.

This is commonly described as consisting of three layers; the True Skin which lies innermost, the Cuticle which is external, and the Rete Mucosum which connects these; but this last is not easily distinguished, except in blacks, in whom it is the seat of the colour. Both it and the cuticle have been usually thought extravascular and inorganic.

The *true skin* is a firm dense membrane, of a fibrous and reticulated texture, extremely elastic, at least in youth and middle age, marked with varied lines exter-

nally, and with very numerous depressions internally, which receive processes of the adipose texture beneath; very fully supplied both with minute bloodvessels and absorbents; containing, in many places, the sebaceous glands or follicles, and perforated obliquely in many others by the hairs, which spring from little bulbs beneath it. It is almost entirely resolvable into gelatin, but requires long-continued boiling for this purpose.

According to the recent and elaborate investigations of Breschet, the structure of the integuments appears to be somewhat different from what has been generally supposed, in the following particulars:

1. The rete mucosum is only the newest and softest layer of the epidermis, *i. e.* is only condensed mucus.

2. The epidermis is not strictly extravascular, for absorbent vessels, although no bloodvessels, may be traced even to its outer layers; and the ducts which pour out the sweat, may be traced through its substance to its surface.

3. In the substance of the skin, the parts destined for its different functions enumerated, appear to be more distinctly separated from each other than has been hitherto supposed; the organs secreting the mucus, which afterwards hardens into the epidermis, may be distinguished from those which secrete the sweat; and the latter send out spiral ducts, which penetrate the epidermis, while the former glands emit straight ducts, which terminate on the surface of the true skin. The organs forming the colouring matter of the skin may even be distinguished from either of the other sets of glands; and all these parts are easily distinguished from the nervous papillæ, which are the organ of touch.

Greater diversity of structure and function are thus attributed to the minute parts of the skin than were for-

merly understood, but not greater than can be easily believed; since we are assured, particularly by the microscopic observations of Ehrenberg, that the complexity of structure bears no proportion to the size of parts in animal bodies.*

An important observation has been lately made by Donné, on the opposite chemical characters and electrical agency of the secretions of the skin, and of those of the internal membranes of the body. The secretions of the skin are acid, except at a few points, and those of the internal membranes, both serous and mucous, with the exception of the stomach, are alkaline; and accordingly, galvanic currents are easily established between the skin and the internal membranes, as also between the stomach and liver during digestion. But the chemical character of all the secretions appears to be easily changed, even by slight disease.†

A degree of vital contraction would appear to take place in this texture occasionally, particularly from the influence of cold, and of certain mental emotions.

The facts mentioned at p. 128, shew that the change of this texture by nutrition and absorption, in ordinary circumstances, must be very slow; but in different diseases, it is obvious that these vital actions in it take place rapidly and extensively.

The surface of this membrane is certainly the scene of three vital processes; the formation of the Cuticle, Perspiration, and Absorption.

The Cuticle is easily detached from the true skin, by the action of a blister, in the living body, and by putrefaction in the dead. It is a thin, very elastic membrane,

* See Recherches sur les Appareils Tegumentaires, &c. Ann. des Sciences Naturelles, 1834, t. ii.; and especially, Pl. x. fig. 36.

† Id. lib. 1834, t. i. p. 125.

composed almost entirely of solid albumen. Its formation is no doubt continual, as it is obviously subject to continual waste from friction, and is much increased or excited by irritation or pressure, as in the palms of the hands or soles of the feet. Although an inconsiderable texture in the human body, when compared with the corresponding parts of many other animals, it is of great importance in the animal economy, particularly by restraining the amount of the vital actions which take place on the surface of the true skin. For this purpose it is especially fitted by the cohesion of its parts, which is such as to transmit any fluid substance very slowly, as appears in the dryness of its surface when it is raised in a blister; and again in the rapid drying of the surface of the true skin, whenever the cuticle is removed from it in the dead body. The analogy, formerly remarked, between the Cuticle, which defends the surface of the true skin, and the mucous secretion which defends those internal membranes that are exposed to the irritation of foreign matters, is most clearly exemplified in cases where a portion of the upper lip has been employed by surgeons to restore a lost part of the columna nasi, and the mucous membrane of that portion of lip, exposed to the air, has gradually acquired the properties of the rest of the integuments.*

The Nails consist of the same material as cuticle, with very little earthy matter, but of much firmer consistence, and more firmly attached to the true skin beneath them, than any other parts of it, and are remarkable for the mode of their growth; their outer layer seems to be formed entirely in the folds of skin at their roots, and pushed forward by continued accretion there, while other layers

* See Liston, Elements of Surgery, Part ii.

are added to their inner surface by the portions of skin over which they pass.

Although the Hair is usually regarded as equally inorganic with the cuticle and nails, yet there are some facts which appear well ascertained, particularly sudden changes of the colour of the hair, from mental emotion, or other causes, which seem to indicate that vital processes of nutrition and absorption go on in this substance itself; but its growth seems to be confined to the bulb beneath the cutis vera.

The colour of the hair depends on exposure to the light, and is no doubt connected either with the formation, or with some alteration, of an oil which is found in the texture. Hair is partially resolvable by boiling in water under pressure, although with different degrees of facility, into a gelatinous matter; but part is decomposed by this process, and gives distinct evidence of containing sulphur.

The vital processes by which the cuticle, hair, and nails are constantly formed, are liable to alteration from heat and cold, and other causes; and especially by those diseases in which inflammation of the skin takes place. The hair drops off sooner, or is sooner changed in colour, in those persons and circumstances, where there is much sweating. The shedding of the hair is a common effect of long-continued febrile action, even independently of cutaneous inflammation; and the separation and renovation of the cuticle, after the specific inflammations of the skin have run their course, appear to be essentially connected with the recovery of health.

The passage of fluids outwards through the cuticle, appears to take place more easily when it retains its connexion with the true skin, through the rete mucosum, than when it is detached by a blister; and is determined

by various causes; by external heat, exercise, and other means of exciting the circulation; by mental emotion; and also remarkably by failure of the heart's action, as in fainting. In this last case, it coincides with the appearance of an unusual proportion of serum in the blood of the large veins;* and both are probably to be ascribed to a tonic constriction of the smaller bloodvessels, no longer distended, as previously, by the impulse from the heart.

The sensible perspiration, or Sweat, appears to contain an excess of lactic acid, a small quantity of the same alkaline and earthy salts, and the same uncoagulable animal matter as the serum, and also an oil, probably in part, but not wholly, formed in the sebaceous glands. The quantity of these substances seems to be much less variable in the healthy state than that of the water which passes off from the skin; because the sweat, like the urine, becomes much attenuated when its quantity is increased.

Even when no fluid is visible on the surface of the skin, a quantity of watery vapour is always exhaled from it, as appears when the hand and arm are confined in a glass jar. The air in immediate contact with the skin has also appeared, in many experiments, as those of Cruickshanks, Jurine, and some of those of Mr Ellis and Dr C. Mackenzie, to contain an unusual proportion of carbonic acid; but the formation of this acid could not be recognised at all in some experiments, such as those of Dr Klapp and Dr Gordon; and in all cases appears to be so small, that this excretion cannot be regarded as an important part of the functions of the skin. Its very small quantity has prevented physiologists from ascertaining whether it is essential to the appearance of this acid, that the skin should be in contact with a gas containing oxy-

* Davy, De Sanguine.

gen ; but, in some experiments by Spallanzani and by Mr Abernethy, this condition did not appear necessary.

The average quantity of exhalation from the human body by the skin and lungs together, *i. e.* the whole loss of weight from these sources, taken together, is stated by Haller, on comparison of the results of many observations, to vary from 30 ounces in the 24 hours in the colder climates, to 60 in the warmer, of Europe ; and by Lavoisier and Seguin it is stated at 45 ounces in the climate of Paris ; but it is liable to very great variation, not only according to the temperature and humidity of the atmosphere, but also according to the diet and habits of individual persons, and the state of repletion of their vessels.

Of this exhalation, it appears from the experiments of Lavoisier and Seguin, that about 2-3ds or 30 ounces are from the surface of the skin, and 1-3d or 15 ounces from the lungs.

The amount of loss sustained by the exhalation from the lungs, has been already stated as in reality only the excess of the exhalation over the absorption habitually taking place there ; but it is more doubtful whether any compensating absorption habitually takes place at the skin.

Many familiar facts illustrate the great absorbing power of the vessels of the true skin, over such matters as are either mechanically forced through the cuticle, or introduced where it has been abraded ; but the possibility of absorption through the entire cuticle is much more doubtful.

Various observations made by Rye, Linning, Fontana, and others, prove, that, in certain circumstances, and especially during fasting, when absorption is unusually active, not only the usual waste of the body by exhalation from the skin and lungs may be suspended, but an absolute

increase of weight may take place during a time when no food or drink has been taken, only to be explained by absorption at the skin or lungs ; and observations on the comparative amount of the ingesta and egesta, and on the loss of weight, of patients in diabetes, have also led to the conclusion, that there must be an excess of absorption over exhalation at these surfaces.* But these observations do not prove that any part of the absorption in question is at the skin.

Of the many observations made by the warm-bath to ascertain this point, the general result may be stated thus ;—That the rate of waste of the body, previously existing, has been generally lowered, sometimes the waste altogether stopped, and, in some cases, an absolute increase of weight to a small amount, has resulted from immersion for half an hour or more ; and this where there was at least probable evidence that the absorption at the lungs had not increased.† These experiments shew, that a certain quantity of fluid may be at least imbibed by the cuticle, and probably absorbed from it.

But in the experiments of Seguin, Rousseau, Dangerfield, and Gordon, made chiefly by applying liquids to the surface of the body, which have a known effect when taken into the blood, on certain secretions (care being taken that the vapours of these should not be inhaled), no evidence of absorption from the skin, when the cuticle was entire, could be procured ; and the different result of two experiments made in the same way by Dr Young, is not enough to set aside the conclusion, that the amount of absorption of liquids in the human body, through the

* See Dill on Absorption by the Skin, Edinburgh Medico-Chirurgical Transactions, vol. ii.

† See Dr Dill's paper, Dr Young's Thesis, Edin. 1817, and Dr Madden's Prize Thesis, 1837.

entire cuticle, where no pressure is used, is in general trifling; particularly when compared with the activity of absorption at the lungs.

More recent experiments, shewing the facility with which gases either intermix with each other, or penetrate into fluids, through the medium of animal membranes,* render it highly probable, that an absorption, as well as exhalation, of gaseous matter may take place through the cuticle; but we have no reason to think that this absorption is important to the animal economy, or its amount considerable, when compared with that at the lungs.

The whole amount of watery excretion from the skin and lungs manifestly alternates, in the healthy state, with that by the kidneys; the effect both of external heat, and of exercise, which increase the former, being to diminish the latter. But the quantity of the secretion of bile, and probably also of mucus in the intestines, though apparently diminished by violent excitation of the circulation, as by hard exercise, does not alternate with the amount of the exhalation at the skin and lungs; being usually increased, simultaneously with these exhalations, both by moderate exercise and by warm seasons or climates.

X. Of Muscular Texture.

The external aspect and vital properties of this texture, the chief seat of vital contractions, have been stated already; and its distribution over the body, and the purposes to which it is applied, appear in the account of the different functions in which it is employed; but some

* See Mitchell on the Penetrativeness of Fluids. *American Journal of Medical Sciences*, vol. vii.

facts may be stated here, chiefly in relation to its chemical composition, and its nutrition and absorption.

Although the smallest muscular fibres appear every where similarly constituted, there is much variety as to their arrangement and connexions in different parts of the body. Those which are destined only to involuntary motion, are generally attached to soft parts; their course is more complex; they are generally of looser texture, and more distensible, than those of voluntary muscles; but their vital contractions appear at least as forcible. Those destined to voluntary motion are generally of denser texture, and redder colour; they are, for the most part, attached to bones and fibrous parts, and are divided by the disposition of their fibres, into straight, radiated, penniform, compound penniform, &c.

By boiling water on muscles, a quantity of albumen, which takes the solid form; of gelatin, which becomes solid on cooling; and of extractive matter or osmazome, which remains in solution; and several salts, are obtained from them; and the fibrin that remains still preserves the original form, though, when perfectly dried, stated not to exceed 17 per cent. of the whole weight. The Osmazome is the principle which gives taste and smell to muscular flesh; it is the most putrescible part of the substance, and is distinguished by its solubility both in water and alcohol: nearly resembling, in this and other respects, the uncoagulable matter of the serosity of the blood.

The subdivision of bloodvessels in the substance of muscles, is not so minute as in those textures where fluids are secreted, and their nutrition and absorption are slow. They are often seen gradually to acquire great increase of bulk, particularly in consequence of frequent excitation; and to waste from inaction, from disease, and from the effects of certain poisons. But their substance is not

easily, if at all repaired, by similar texture, after laceration or rupture; and they are very little liable to any such alterations in disease as imply rapid deposition and absorption.

According to Sir E. Home, and to Prevost and Dumas, the muscular fibres are composed of globules precisely similar to those of the blood; and it has been lately stated by Du Trochet, that galvanism applied to a drop of blood, kept fluid by the addition of a little alkaline solution,—or to the yolk of an egg diffused in water, determines the formation of rows of globules, which contract after the manner of muscular fibres.* But the analogy of this to the formation of muscular fibre out of the blood, is certainly not to be relied on.†

It may be stated here, in general terms, that muscles are useful in the animal economy, by vital contractions, directed to one or other of the three following ends. *First,* To diminish a cavity which they surround, as in the case of the heart, stomach and intestines, bladder, &c. *Secondly,* When both of their extremities are fixed, or nearly fixed, to alter their own direction, and thereby expand or compress adjoining parts, as in the case of the diaphragm, buccinator muscle, &c. *Thirdly,* Where one of their extremities is fixed, and the other moveable, to draw the latter towards the former, as in the case of almost all the strictly voluntary muscles of the trunk and extremities.

XI. Of Nervous Substance.

It is necessary here, in the first place, to recollect the

* Annales des Sciences Naturelles, t. xxiii.

† See Baly's Muller, p. 133, *et seq.*

different parts of which the Nervous System, in man, and other vertebrated animals, consists; the Brain, Cerebellum, Medulla Oblongata, and parts connecting these, enclosed within the cranium; the Spinal Cord, situate in the canal of the vertebræ: and the Nerves, originating from these, and extending, by innumerable ramifications, probably to all parts of the body in which vessels can be traced: next, the protection given to the larger masses of the nervous system by the bones of the head and spine, and by the three membranes which envelope them within these bones; and to the nerves, by their concealed situation in most parts of the body, and by the firm membrane investing them; and lastly, the division of the nervous matter into grey or cineritious, and white or medullary, and the general disposition of these; the grey matter covering the white in the convolutions of the brain and cerebellum, lying within it in the spinal cord, and alternating with it, in different forms, in the tuber annulare, and in various of the central parts of the brain. The nervous systems of animals without vertebræ are so differently constructed, that the analogy of their parts to those of the human brain and nerves is not to be trusted.

The outer surface of the serous membrane which immediately invests the brain and spinal cord, is always moistened by an attenuated serous fluid, which is confined beneath the arachnoid on their exterior, and contained within the ventricles in the interior of the brain; and these two portions of the fluid, in the natural state, appear to communicate by the small opening at the extremity of the fourth ventricle.

As membranes continuous with the pia mater descend between the convolutions, and into the cavities or fissures of the brain, no part of the nervous matter there is distant from the vascular membrane, from which it derives

its blood, and on which the vessels ramify minutely before they penetrate it; and the same holds of the nerves, all of which are composed of great numbers of very slender filaments, bound together by cellular substance, which receive minute vessels from the neurilema.

The nervous matter, in the medullary substance, is arranged in fibres, which are in few places distinctly perceptible in the recent state, but become obvious after hardening by alcohol, boiling oil, diluted nitric acid, &c.

The following general facts, in regard to the anatomical distribution of the nervous system, appear to be those which most immediately connect themselves with its physiology.

1. The nerves may be divided, as was pointed out by Sir Charles Bell, into Symmetrical and Irregular; the distinctions of which are, that the former arise from the larger masses of the nervous system, by double roots, an anterior and a posterior; that there is a ganglion on the posterior, where it passes through the dura mater; that they pass out, in general, nearly at right angles to the surface from which they arise, and do not cross each other, nor inosculate till they are at some distance from that surface; and that they form a complete system, supplying all parts of the body, whether these have other nerves or not; whereas the irregular nerves have no such regular arrangement of double roots, pass out in more various directions, several of them cross, and some inosculate freely with the other class of nerves, and so unite the different divisions of the frame; and they always go to parts which have likewise nerves of the symmetrical class.

The first class comprehends all the pairs of the spinal nerves, thirty in number, and the fifth pair of the cerebral. There is more difficulty as to the arrangement of the cerebral nerves; but physiological facts, to be after-

wards stated, seem clearly to indicate that those cerebral nerves which go to muscles only, the third, probably the fourth, the sixth, portio dura of the seventh, and ninth, as well as the smaller or anterior branch of the fifth, correspond to the anterior portions of the spinal nerves, and are to be ranked in the symmetrical system. The nerves strictly belonging to the irregular class, are the eighth pair, the spinal accessory nerves, the phrenic and external respiratory nerves of Sir C. Bell, and the great sympathetics. The first, second, and portio mollis of the seventh, the functions of which are well known, may be either ranked as irregular nerves, or be separated from both classes.

2. Some of the nerves pass to the organs to which they are destined, and are subdivided there, without inosculating with any others on the way; but by far the greater number of the nerves are connected with others, either by Plexuses or Ganglia. The former are multiplied unions and separations of the larger branches of nerves, without any intervening substance; the most striking instance is the axillary plexus, formed by the nerves of the symmetrical system, going to the arm; but a similar intermixture of filaments takes place in the sciatic and crural nerves, which are formed by the lumbar and sacral nerves; and the irregular nerves of the trunk of the body are very generally connected in this way. The ganglia are oval or roundish bodies, formed in part of a vascular pulpy substance, within which there is a separation and reunion of nervous filaments entering them, as close and intimate as that of the absorbent vessels within a lymphatic gland. These are found on the posterior roots of the symmetrical nerves; but the greater number, and most characteristic examples, of the ganglia, are found on the great sympathetic nerve (the course of which is paral-

lel to the spinal column), at the points where it crosses and communicates with the symmetrical nerves that pass out from the spinal cord. Many internal parts have their nerves exclusively from these ganglia; and these are thereby connected with the whole extent of the spinal cord, and hardly with any individual point of it more than with another.

3. All the nerves, symmetrical and irregular, have their origin either from the Spinal Cord itself, or from parts at the base of the brain, not higher than the tubercula quadrigemina and crura cerebri, which are easily shewn to be its prolongations, *i. e.* they arise from what has been called the *Cerebro-Spinal Axis*, on which the brain and cerebellum are superimposed.

4. The Spinal Cord is obviously divided into two similar portions by its anterior and posterior median fissures; and each of these halves of the cord is again, though less obviously, divided into an anterior, middle, and posterior column. The anterior and posterior roots of the spinal nerves come off just where the anterior and the posterior join with the middle column; and the small quantity of grey matter within the cord projects towards the same points. The anterior columns appear to lead up to the corpora pyramidalia, the middle to the corpora olivaria, and the posterior to the corpora restiformia. The course of the chief fibres of all the columns of the spinal cord, as traced after hardening the nervous matter, is longitudinal and uniform, as high as the medulla oblongata; but at the lower part of the corpora pyramidalia, the course of the fibres, especially of the anterior and middle columns, becomes more complex, and is traced with difficulty; and a partial decussation of the fibres, from side to side, below and behind the corpora pyramidalia is observed. This decussation, according to the observations

of Sir Charles Bell, extends to the whole of the anterior and middle columns, which pass forward, through, and behind the tuber annulare, to form the crura cerebri; and another set of fibres, from the posterior columns, pass through the corpora restiformia into the cerebellum without decussating. Mr Solly appears to have established (what indeed had been partially described before by Rolando and others) that there is a decussation from before backwards, as well as from side to side,* in the medulla oblongata; a part of the anterior columns of the spinal cord, dipping backwards, behind the corpora olivaria, and passing by the corpora restiformia into the cerebellum.

5. The Brain proper, may be considered as composed of a central nucleus, and of folded laminæ or convolutions set around it at right angles to its surface. The convolutions consist of plates of medullary substance, with coverings of cineritious matter, not satisfactorily shewn to be continuous with the fibres composing these plates.

From the descriptions of those who have examined the course of the fibres in the brain the most accurately, and particularly of Reil, it would appear that the central nucleus consists of two sets of medullary fibres, one of which has been called vertical, the other horizontal, from their most general directions, though both are much convoluted in some parts of their course. These intersect one another variously in different parts of the brain, and have portions of grey matter, of various size and figure, interposed among them.

The vertical fibres are continuous with those that ascend from the spinal cord, through the crura cerebri, after crossing the tuber annulare. They pass up on the outer side of the thalami nervorum opticorum, and radiate

* See Phil. Trans. 1834, and his work on the Brain, and Nervous System.

thence, in all directions, to the bottom of the convolutions; many of them, on each side, passing obliquely through the corpus striatum, in a broad band (the inner wall of the capsule of Reil), which divides it into two parts; and some of them terminating in the grey matter of the corpus striatum. The thalami and corpora striata, as well as the corpora quadrigemina, are appendages to this vertical portion of the fibres. It is probable, though not distinctly demonstrable, that these vertical fibres are continuous with, and terminate in, the plates that form the central medullary portion of the convolutions.

The horizontal fibres are confined to the brain, not descending to the spinal cord: the principal parts which they constitute in the central part of the nucleus are, the corpus callosum, and the different commissures, where they run transversely; and the fornix, and its crura, where they run longitudinally. Towards the exterior of the nucleus, there are found not only the prolongations of the transverse horizontal fibres, but also other fibrous bands, which are wrapped round the base of the convolutions, and connect these with each other.*

The lobes and lobules of the cerebellum consist, like the convolutions of the brain, of medullary fibres arranged into laminæ or plates, which are set around an irregular nucleus. In that nucleus, there are transverse or horizontal medullary fibres uniting the laminæ at their base; but the greater part of the central nucleus of the cerebellum consists of fibres continuous with the medullary

* See Reil's Papers, translated by Mayo, in his Anatomical and Physiological Commentaries. Gordon on the Structure of the Brain. Report of a Committee of the French Institute on Gall and Spurzheim's Anatomy of the Brain, in Edinburgh Medical and Surgical Journal, vol. v.; and Report by Cuvier on Flourens's Experiments on the Nervous System, in Journal de Physiologie, t. ii.

plates of the lobules, which pass forward to connect themselves with the cerebro-spinal axis by three columns; *first*, By the corpora restiformia, which connect themselves with the posterior columns of the spinal cord; *secondly*, By the crura cerebelli, which form the tuber annulare, by crossing and encompassing the larger portion of the spinal cord on its way to the crura cerebri; *thirdly*, By the valve of Vieussens, and its pillars (originating partly in the corpus dentatum, within the medullary portion of the cerebellum), which connect themselves with the crura cerebri, below the corpora quadrigemina.

The Ventricles or Central Fissures of the Brain and Cerebellum, may be said to result from the separation of the vertical portions of the two hemispheres from one another, and from the apposition of the horizontal portions over them.

The chief results of the microscopical investigation of the structure of the nervous system, by Sir E. Home and Mr Bauer, and more particularly by Ehrenberg, Treviranus, Valentin, Remak, Muller, and others in Germany, may be stated as follows:—

1. The white nervous matter seems to be every where in the form of fibres or filaments, of somewhat various diameters; and these fibres are certainly in some parts, probably in all parts, tubes containing a soft or semi-fluid matter, lying parallel to each other, but not coalescing.

2. In the brain and cerebellum, spinal cord, nerves of the special senses, and sympathetic nerve, the greater number of the tubes have the articulated or jointed, or, as Ehrenberg expresses it, varicose appearance delineated by Sir E. Home, Raspail and others, while in the nerves, the tubes are cylindrical; but this difference appears distinctly from the observations of Muller and others, to

be owing only to the firmer texture of the tubes in the nerves, resisting the effect of slight pressure, which gives the jointed appearance to the fibres in the brain.

3. The contents of the tubes in the brain, cerebellum, and spinal cord, are uniform and translucent, but in the nerves they are somewhat more opaque and granular, and may be forced out of the cut ends of the tubes themselves by slight pressure,—the tubes here being larger, and of somewhat firmer consistence than in the brain.

4. There is no difference in the structure of the cerebro-spinal nerves, according as they will afterwards appear to be destined to sensation or motion.

5. The ultimate terminations of the nervous fibres are in the different organs of the body, on the one hand, and in the cortical matter of the brain on the other. At both extremities they are surrounded by many minute vessels; in some instances, as on the retina, they seem to terminate in single papillæ, more generally in farther subdivision, and subsequently anastomoses with one another; and in the grey matter of the brain and cerebellum, according to Ehrenberg also in the retina, these anastomoses are intermixed with globules of a different matter, which is found also interposed between the fibres in the ganglia, and is not disposed in the fibrous form. This globular matter has been represented by Ehrenberg as apparently made up of the central portions of the globules of the blood, deposited nearly unchanged; but this statement is not hitherto confirmed.

6. The medullary fibres of the cerebro-spinal nerves pass through the ganglia unaltered, except by subdivision and reunion, and each of these fibres appears to pass without anastomosing with any other from its origin to its termination.

7. Connected with the grey granular matter in all the

ganglia, there are *fibres of grey matter*, which extend along the branches of the sympathetic nerve, and more sparingly along the cerebro-spinal nerves, chiefly from the ganglia towards the terminations of the nerves, but partly also towards the spinal cord, and which are distinguished from the white medullary fibres, by being much smaller, quite homogeneous in appearance, having no distinction of containing and contained matter, and here and there swelling out into minute ganglia, even in the substance of the nerve. To these the somewhat theoretical name of *organic fibres* has been given.*

The apparent implantation of the vertical fibres of the brain and cerebellum on the grey matter of the convolutions and lobules, and on that of the corpora striata—the origin of some of the fibres of the crura cerebri in the corpus dentatum,—and the extension of the grey matter of the spinal cord towards the origins of most of the nerves, —have led to the opinion, that it is essential to the functions of medullary fibres that they should terminate, by one extremity, in cineritious substance. But strong objections to this opinion have been stated, at least to this being the use of the grey matter of the spinal cord, by Magendie and Desmoulins, particularly that in many fishes and reptiles cineritious matter exists in the brain, but not in the spinal cord, yet the nerves arising from the spinal cord are fully adequate to their functions; and, again, that the functions of the spinal cord, in regard to sense and motion, appear, from experiments to be afterwards stated, to reside in its surface chiefly, and not in its interior, but the grey matter is found in the interior only.

* See Ehrenberg's Observations on the Brain and Nerves, translated by Dr Craigie, in Edin. Med. and Surg. Journ. Oct. 1837; and Baly's Muller, book iii. sect. i. ch. 1. 6. and sect. ii. ch. 4.

The nervous matter appears to be of more complex chemical composition than many other animal solids. By the action of hot alcohol, are obtained from it a quantity of albumen which remains undissolved, a quantity of oil which is deposited on cooling, and a quantity of extractive matter resembling osmazome, which remains in solution, along with some salts. A small quantity of phosphorus, and of sulphur, have also been obtained from brain. The whole of these, when perfectly dried, constitute only 20 per cent. of recent cerebral substance.

No movements have ever been seen in any small portion of nervous substance, even under the microscope, and when examined at the time when its peculiar functions were undoubtedly in exercise. But the whole brain and spinal cord, when exposed, may be seen to be slightly agitated by the impulse of the blood at each systole of the ventricles of the heart; and more distinctly, to be elevated by the retardation, and depressed by the acceleration, of the flow of the blood in the great veins, in expiration and inspiration.

Besides the peculiarities formerly noticed as to the arterial and venous circulation in the brain and cerebellum, —the effect of which is to diminish the impetus with which the blood enters the brain, and diminish the pressure on it from stagnation of the blood leaving it,—there is this farther peculiarity as to the circulation within the head, that, being carried on within a cavity with unyielding sides, it is protected from the pressure of the atmosphere, which acts on the vessels leading into it and out of it; and the consequence of this is, that the quantity of fluids within the cranium must be always almost exactly the same; no unusual quantity either leaving it, or entering it, without an equal quantity being introduced or expel-

led; unless some of the solids within the cranium either suffer compression (which they hardly admit), or else undergo alteration of quantity, which they cannot do quickly.

But although the whole quantity of fluids within the head can hardly be changed, within any short space of time, yet the impulse of the blood on the nervous substance, and pressure thereby caused, are no doubt very liable to change; and farther, various facts shew, that the relative proportion of blood in different parts of the encephalon, and even the relative proportion of blood in the vessels, and of serum exterior to them, are occasionally much and rapidly altered.*

Increased nutrition of the substance of the brain or cerebellum, after growth is over, cannot take place without disease, from the pressure on the cranium it must occasion; but appears evidently to occur in a particular diseased state, described as Hypertrophy of the Brain. Alterations of the nutritive process in this texture from disease are not uncommon; but do not seem to take place so rapidly as to indicate frequent change of the substance of the brain in the progress of life. The facility of increased absorption appears in many cases of disease, where tumors grow on the surrounding membranes or bones, where blood is effused into the brain, and where fluid is effused into the ventricles, especially in the case of Chronic Hydrocephalus, where the sutures of the skull are enlarged; for, in whatever manner it may be that the apparent unfolding of the convolutions in that case is accomplished, it is certain that a quantity of the substance intervening between the ventricles and convolutions must be absorbed away; and that, in some such cases, the brain is considerably reduced in weight.†

* Kellie, Edinburgh Medico-Chirurgical Transactions, vol. i.

† See Gordon on the Structure of the Brain.

It is certain, especially from the experiments of Cruickshanks, Haighton, Flourens, and Prevost, that injuries of the nervous substance may be gradually repaired in the living body by materials which shall assume the true vital properties of this texture, now to be considered. An observation of Mr Mayo on the apparent want of such power of reparation where the fifth nerve has been cut within the dura mater, where it has no neurilema, makes it probable, that the nerves at least are very dependent, for such power of reparation on the vessels of surrounding cellular texture.

It is next to be observed, that Nervous Matter, in the living body, possesses very peculiar and strictly Vital Properties, which are made known to us by the effects on the functions of other organs, produced by physical impressions made on various parts of the Nervous System. These have been already briefly and incidentally noticed, but demand fuller consideration here.

I. Certain muscles are *directly excited* to contraction by irritation of certain parts of the Nervous System, without any impression being made on the muscles themselves. In regard to this general fact, the following things are to be observed.

1. The fact in question is fairly exemplified, only when those stimuli are applied to nervous matter in an animal stupified or just killed, or to an amputated limb, when no effects of sensation embarrass the results

2. The chief physical stimuli that answer this purpose, when applied to the Nerves, Spinal Cord, or Brain, are mechanical impulse or sudden pressure, certain chemical acrids (the effect of which, in exciting muscular contraction when applied to *nerves* only, is unequivocally a vital phenomenon), and electricity or galvanism.

3. This effect of irritation of nervous matter is prevented from taking place whenever the communication, by sound nerve, between the point irritated and the muscle to be excited, is interrupted; but not when the communication between the point irritated and the brain is interrupted.

4. This phenomenon is observed, as has been already stated, on irritation of the nerves of certain muscles only; many muscular parts, especially the Heart and Intestines, having appeared in the experiments of Haller, Fontana, Bichat, and many others, quite unaffected by irritation of their own nerves, and not distinctly excitable (though their movements may be modified), by irritation of other parts of the Nervous System. And from Mr Mayo's experiments particularly, it appears that the distinction between the muscles that are, and those that are not, excitable in this way, coincides very nearly, if not exactly, with that between muscles destined to voluntary and involuntary motion;* perhaps more precisely with that between muscles which are destined to be directly excited to contraction by certain acts of Mind, and those which are not destined to be so *excited*, although their irritability is liable to be *modified* by mental acts.

5. This phenomenon is not seen on irritation of all the nerves of those muscles that are subject to it, but on irritation of certain of these nerves only. For it has been ascertained by the experiments, first of Sir C. Bell, and afterwards of Magendie, Beclard, Mayo, Muller, and many others, that hardly any muscular contractions can be excited by irritation of the posterior portions of the spinal nerves, or of the ganglionic portion of the 5th nerve, although strong contractions may be excited in this way through the anterior portions of the spinal nerves,

* Mayo's Outlines, p. 50.

and the 3d, 4th, anterior portion of the 5th, the 6th, portio dura of the 7th, 8th, and 9th cerebral nerves. And Sir C. Bell has farther shewn, from what is seen on tracing the nerves of the face, that this difference does not depend on the nerves first mentioned not supplying muscles,—but that they supply muscles which they cannot excite.*

6. Another fact may be stated here as to the excitement of muscular contraction by the physical irritation of nerves; viz. That, in certain instances, such irritations applied to nerves, and especially to the extremities of nerves in *distant* parts, chiefly on the skin or mucous membranes, excite that contraction. In such cases two conditions are necessary, *first*, that the nerves irritated shall have their origin in the posterior columns of the spinal cord, *i. e.* shall be of that class, to which we shall afterwards find that the faculty of exciting sensation belongs; and *secondly*, that the spinal cord, as a medium of communication between the part irritated and the muscles excited be entire. Hence, contractions so excited have been ascribed to what has been called the Reflex Function of the Spinal Cord. In general, and for useful purposes, this kind of excitement of muscular action is attended with sensation; but as cases have occurred in the human body, where muscles have been excited in this way (*e. g.* by tickling the soles of the feet) when sensation was at a stand, it has been reasonably argued by Dr Marshall Hall and others, that sensation cannot be an essential condition to this kind of action. It is to be observed, however, that any movements of this kind in voluntary muscles, which may be excited in the undoubted absence of sensation, appear to be irregular and ineffectual for any useful purpose.

* Phil. Trans. 1826.

7. Muscles which have nerves from the spinal cord are excited to contraction, not only by irritation of their nerves, but also of the spinal cord itself, between the origin of these nerves and the brain. This irritation acts most powerfully on those muscles which have nerves from the immediate neighbourhood of the points irritated. But it has been farther shewn by experiment, that this power of exciting muscular contraction, when itself irritated, does not reside in all parts of the spinal cord, but chiefly in its anterior surface, in a slight degree only, if at all, in its posterior surface, and hardly at all in its internal parts.*

Irritation of the posterior surface of the spinal cord, and posterior roots of the spinal nerves, has appeared in some experiments to cause contractions, although feeble, confined to those muscles which *extend* the body and limbs, while irritation of the anterior surface, and anterior roots, acted chiefly, and more forcibly, on the flexor muscles.†

8. Muscular contractions have been very often directly excited, in experiments on animals, and in cases of injury or disease in the human body, by irritations of the parts of the nervous system situate within the cranium. But it has been long known, from experiments by Zinn, Lorry, Haller, and others, that much of the brain and cerebellum may be injured without any such effects resulting; and more recent experiments, particularly those of Legallois, Dr Wilson Philip, and of Flourens, Magendie, and Fodera, have led to the conclusion, that *no irritation of the Brain proper, or Cerebellum, is necessarily effective* in producing muscular contraction; but that this effect uniformly results from irritation of the *medulla oblongata*, and parts inferior to the corpora quadrigemina,

* Magendie, Journal de Physiologie, tom. iii.

† Bellingeri, Archives de Medecine, 1825.

—no doubt therefore of the fibres which ascend to the brain from the spinal cord through these parts; and that all irritation or injury of parts superior to this, excite muscular contraction only in so far as they extend directly or indirectly to, and affect, the medulla oblongata.*

When muscular contraction, or convulsive movement, is produced by injury or disease of either hemisphere of the brain or cerebellum, it has generally been observed on the opposite side of the body; and this has been ascribed to the decussation of the fibres at the lower part of the corpora pyramidalia. But this *crossing* of the effect of injury to the opposite side has been observed, in the human body, from disease of the brain, in the functions of the fifth, seventh, and ninth nerves, which arise nearer the brain than the decussation of the pyramids; so that, if the effect of an injury of the right side of the brain is carried down to the medulla oblongata by those fibres which decussate there, it must be transmitted from that point, not only downwards along the opposite side of the spinal cord, but upwards along the opposite side of the medulla oblongata and tuber annulare.

To the effects of injury or irritation, either of the spinal cord or brain, on muscular contraction, equally as to those of injury of individual nerves, it is an essential condition, that there be a communication, by sound nervous substance, from the point irritated, to the muscle that contracts.

9. In all these cases, the effect of injury of nervous matter, in exciting muscular contraction, is chiefly observed when it is produced *suddenly*,—gradual alteration, by injury or disease, even of the nerves or spinal cord,

* See particularly Flourens, Recherches Experimentales sur le Systeme Nerveux; Fodera in Journal de Physiologie, tom. iii.; and Magendie, do. do.

and still more of the brain and cerebellum, having often been observed to a great extent where no convulsive motions had ever taken place.

II. The contractile power of many, perhaps of all moving solids, is *liable to alteration* from physical causes acting on the Nervous System, which act, not as simple irritants, exciting contraction, but as stimulants or sedatives (*see p.* 11.) exalting or depressing the vital power. This effect of physical impressions on the Nervous System is chiefly seen in the involuntary muscles. It is imperfectly understood, and is with difficulty distinguished from the effect of sensations; but the following facts leave no room for doubt as to its existence.

1. It appears from the experiments of Legallois, that by a certain amount of mechanical injury of any part of the spinal cord, the heart's action may be very much and instantaneously weakened, or even suddenly suppressed; and from the experiments of Dr Wilson Philip, that the same may happen from a certain degree of injury of the brain; but that from slighter injury, either of brain or spinal cord, inflicted on an animal in a state of insensibility, the heart's action is sensibly quickened.*

2. It appears also from the experiments of these authors, and especially of Flourens,† that great mechanical injury of the brain or spinal cord weakens the circulation in the capillaries sooner, and in a greater degree, than that in the large arteries, and even, that such injury of the spinal cord is often seen to affect immediately the flow of blood in the capillaries of those parts only, which have their nerves from the injured portions of the spinal cord.

* Experimental Inquiry, Exp. 20, 21, 22, 34, 38.

† Recherches Experimentales, p. 190 and 196.

3. Those mechanical injuries of the human body, which cause insensibility by general concussion of the system, at the same time manifestly and sometimes irretrievably depress the circulation; which effect it is reasonable to refer to an impression on the nervous system, because of the accompanying insensibility (which, as we shall see, implies affection of that system); and because it is just similar to the effect produced, in the experiments now mentioned, by injuries of the nervous system, without much general concussion of the body. In some such cases of concussion in the human body, as well as in such experiments, violent convulsions of voluntary muscles attend the insensibility, and the failure of the heart's action;—the same impression on the nervous system which excites the voluntary muscles, acting as a sedative on the vital power of the heart.

The inordinate action of the bladder, and consequent incontinence of urine, which ensue, in many cases, after injury or disease of the spinal cord, have also been regarded as an example of increased vital power in a muscular part, from physical irritation of nervous matter; but where this effect on the bladder has taken place gradually from this cause, it ought probably to be ascribed to the inflammatory action which in these circumstances is apt to supervene in the mucous membrane, and the cause of which will be considered under the next head.

It appeared in the experiments of Dr Wilson Philip, that the effect produced on the heart's action, by impressions made on the nervous system, was nearly in proportion to the extent of nervous matter on which these impressions were made, and was nearly the same, in whatever part of the cerebro-spinal axis the injury was inflicted*; and accordingly, both in the case of concussion, and in

* Experimental Inquiry, p. 114, and 115.

several diseases (*e. g.* in hydrocephalus and some cases of apoplexy), in which the heart's action is peculiarly influenced by changes in the nervous system, it may be observed that these changes extend to a large surface of nervous matter. It is certain that the circulation in the arteries of a limb may be sometimes observed to be much weakened immediately after a paralytic stroke, when there may be no evidence of more than a very small portion of nervous substance being injured; which is obviously opposed to the idea, that this kind of influence on contractile parts, results only from impressions made on large portions of the nervous matter; but it will afterwards appear that this influence of partial palsy is probably *indirect*, and reconcilable with that principle.

III. Although we gave reasons for thinking that Secretion and Nutrition are truly independent of nerves, yet several facts shew, that physical impressions on, or injuries of, the nervous system, materially and variously *influence these functions*, as well as the circulation in the small vessels which are their seat. This kind of influence of physical impressions on nervous matter, is also imperfectly understood, and not easily distinguished from the effects of mental acts; but it seems exemplified in the following instances:

1. The effect of section of the eighth nerve in the neck, is not merely suspending the secretion of gastric juice at the stomach (which is a somewhat ambiguous case), but also in exciting a degree of inflammatory action there; in preventing the usual quantity of effusion of mucus in the intestines, even when arsenic has been swallowed;* and, on the other hand, in producing condensation, and chan-

* Brodie, Phil. Trans. 1814. This result, however, appears, from subsequent experiments by Dr Reid, not to be constant.

ging and increasing the secretion, in the lungs and bronchiæ.*

2. The effects (viz. inflammation, ulceration, and sloughing), produced on the eye-ball, and in some instances on the membrane of the nose, and on the gums, as was first ascertained by Magendie, by section of the fifth nerve, which supplies these parts; and likewise, in a less degree, by section of the sympathetic nerve in the neck,†—effects which have also been seen in some cases in the human body, from disease of the fifth nerve.

3. The inflammatory condition, with increased and altered secretion, of the mucous membrane of the bladder, in many cases of paraplegia, dependent on injury of the spinal cord.

The diminished nutrition and diminished secretions (*e.g.* of the skin) often observed in a limb which has been for some time palsied, by section of its nerve, or disease of the brain, may be thought to illustrate the same point; but these effects are perhaps sufficiently explained by the total inactivity of such a limb.

It is to be observed, that such effects as those now stated, on secretion and nutrition, have been observed only in certain parts of the body, and chiefly from injury of the sentient nerves of these parts, and the secretions which are changed, are generally mucous secretions, which are habitually excited by irritations producing sensation. It may therefore be reasonably conjectured, that the effect of the section of the nerve is merely to suspend the sensations of the part, and thereby greatly diminish or alter its usual secretions; and, as these secretions serve as a defence from the irritation of foreign matters, to which

* Wilson Philip, l. c. Swan, Essay on the Connexion between the Action of the Heart and Arteries and the Nervous System.

† See Dupuy, Journal de Medecine, t. xxxvii.

these parts are habitually exposed, the effect of their diminution or change is to dispose the parts to inflammation from that irritation. This conjecture is supported by the fact, that inflammation of mucous membranes, and among others of the Tunica Conjunctiva of the eye, is observed in other cases, where there is great debility of the circulation, deficient secretion, and insensibility, as in animals kept long fasting, and in the last stage of Fever. On this supposition, changes in secretion or nutrition are not the direct effect of the injuries of the nerves, but are to be ascribed to the loss of the sensations by which certain secretions are habitually excited and modified.

These statements of physical phenomena, however, illustrate the very peculiar powers, known only by their effects on other parts of the animal frame, which the Nervous System in living animals possesses. Only one theory, in explanation of these powers, appears to deserve attention, viz. that which ascribes them to Galvanism, evolved in the animal frame, especially by the contact of nervous with muscular substance. It is known that, by the contact of these substances, galvanic phenomena in a slight degree may be produced; and that galvanism, however evolved, is a powerful stimulant of muscular contraction, —in an excessive degree, is a powerful sedative,—and has also appeared frequently to influence the capillary circulation and secretions.

It appeared also, in some experiments by Dr Edwards, that when the nerve and muscle of a frog were laid on a good conductor of electricity, irritation of the nerve had much less effect in exciting the muscle, than when they were laid on a non-conductor; which he ascribed to the galvanism supposed to be excited in the nerve being car-

ried off by the conductor of electricity in the former case, and therefore not affecting the muscle.*

But whatever be the true explanation of this fact, the following general objections may be stated to the Galvanic theory of Nervous actions, such as we have hitherto considered them.

1. The causes which excite, in the highest degree of intensity, those changes in nerves by which muscles are excited (*e. g.* such causes as by bruising with a probe, or pricking with a pin), seem quite inadequate to the production of a sudden and powerful galvanic influence.

2. We have seen that these causes do not act on all nerves, and through them on all muscles which they supply, but only on the nerves of certain muscles, and only on certain of these nerves.

3. We have seen that the power of exciting muscular contraction is so far from residing in nervous substance in general, that it resides on one surface of the spinal cord, and not on the other,—nor in its centre; nay, it resides in one part of a nervous fibre, in the medulla oblongata, and not in another part of the same fibre, half an inch higher in the brain.

4. While the changes in the nervous matter, which excite muscles to contraction, take place only in certain parts of the system, those which exalt or depress the vital power of muscles, appear to take place especially in others, and therefore affect especially other muscles; and the same cause (*e. g.* a violent concussion) which produces one of these effects exclusively in one nerve, may produce the other in another nerve, immediately adjoining it.

The experiments of Person and of Muller have shewn farther,

* Ann. des Sciences Naturelles, t. v.

1. That no galvanic action can be detected by the finest galvanometer in a nerve, at the moment when some change, consequent on its irritation, and transmitted along it, is exciting a muscle to contraction.

2. That a sensitive nerve, going to a muscle, is equally capable as its motor nerve, of conducting a galvanic current to that muscle, and thereby exciting it; although no irritation, confined to that sensitive nerve, has any power of exciting the muscle to contraction.

3. That such an injury of a nerve, as completely prevents any irritation, above the injured part, from exciting the muscle supplied by it, has no effect in preventing the transmission of a galvanic current from the upper part of the nerve through the injured part, so as to excite that muscle.*

These facts unequivocally indicate, that if it be Galvanism which enables nerves to act on muscles in the living body, it is galvanism excited by means, and subjected to laws, very different from what we observe in examining the galvanic phenomena of dead matter. And this is equivalent to saying, that nerves act on muscles in the living body, in virtue of certain *vital powers*.

The most comprehensive and least theoretical general name that we can give to the changes in the nervous system that are referable to these powers, is that of Nervous Action, or Nervous Agency.

* See Journal de Physiologie for 1830, and Annales d'Histoire Naturelle, 1831. See also Baly's Muller, p. 633, *et seq.* It is well observed by Muller, that so far from the phenomena of electric fishes favouring the hypothesis of the electric action of nerves, "the very fact of the existence, in these fishes, of organs constituted after the manner of galvanic piles (described by Hunter and others), is unfavourable to that theory; for if electricity were the active principle of the nerves, these fishes would require only conductors, not a special galvanic apparatus."—Ib. p. 639.

CHAPTER IX.

OF THE ANIMAL FUNCTIONS IN GENERAL.

We have attributed peculiar Vital Properties to the Nervous System, in consequence of the observation of certain merely physical phenomena. But these phenomena are the effects of injury and violence; and we have no reason to think that, in the natural and healthy state, those properties are frequently, if at all, called into action in this way. We believe the phenomena last stated to be only indications of th powers which are given to the Nervous System in living animals, in order that it may be the seat, and the instrument, of Mental Acts.

These Mental Acts, and all the functions in which they have a necessary share, constitute the Animal Life, or Animal Functions, as distinguished by Bichat and others. Some general observations on these functions may be introduced here, and will simplify the discussion of the remaining departments of Physiology.

I. As the words Sensation and Thought express simple ideas, it is impossible to define them; but no man can be at a loss as to their meaning, who is told that they apply to those changes which all men continually experience within themselves; and to which all have been in the habit of applying such terms as Sight, Touch, Recollection, Judgment, Joy, Sorrow, Hope, Fear, &c. The word Mind is defined by saying, that it is that which undergoes the changes, or performs the acts, or exists in the states, to which these different terms are applied.

Neither does any man feel any difficulty in understanding the difference between what are strictly called Sensations, and what are called Thoughts, when he is told that the former term is applied to the changes which he experiences, when an impression is made on any of his external senses, and the latter to those other changes of which he is internally conscious, but which do not correspond to any impression made on his senses, *e. g.* Recollections, Emotions, or Judgments.

When we reflect on the essential nature of this difference, which every one must have habitually recognised, long before he has made it an object of attention, we find that the name Sensation is given to those changes which (in the adult state at least) are attended with an instantaneous conviction, that they depend immediately on a cause that is *independent of, and external to, the sentient mind* that undergoes the change. How this conviction of the independence of its immediate cause is acquired, *i. e.* in what circumstances it first arises in the mind, we do not now inquire; but it is a part of the Natural History of our mental constitution, and is the attendant, and the essential characteristic, of that mental change, to which we give the name of Sensation.

The immediate cause, independent of, and external to, the sentient mind, to which we naturally ascribe the excitation of sensation, is what we call Matter; and we attribute to it different qualities, corresponding to the different sensations which it excites in our minds; or, as it is otherwise expressed, we *perceive* it, and its qualities, by our senses.

If this account of the strict meaning of the terms Mind and Matter be correct, no more need be said in order to shew, that it is illogical and absurd to speak of these, otherwise than as separate existences; because any one,

who has correctly apprehended the meaning of the two terms, has already formed the judgment, that the one is independent of the other.

The one term is applied to the individual being, which we naturally and intuitively judge to be the *subject*, or *seat*, of those changes which we call Sensations or Thoughts; it is that which actually exists in the different states, to which we give these names; and we cannot apply the term to any thing which we judge to be separate from, and independent of, those feelings. The other is known to us only as the *object* of sense: the cause, judged to be independent of our sentient minds, of certain of the changes of which these minds are susceptible; and unless we have already formed the judgment of its independence, we cannot apply the term. Those who distrust that judgment, will not believe in the existence of Matter; but those who believe in the existence of Matter (unless they can explain how they got that notion, otherwise than as above stated), cannot, without absurdity, identify it with Mind.

The same facts are expressed by saying, that for the existence of Matter, we have the ***Evidence of Sense***, for that of Mind the ***Evidence of Consciousness***; and that we inquire into the one by ***Observation***, and into the other by ***Reflection***. For the existence of any other sentient and thinking minds but our own, we never can have either of these kinds of evidence; it is not known to us, either by consciousness or observation, but is always a matter of *inference*.

It is to be observed, then, that we give the name Object of Sense, to those things only which we judge at the moment when we apprehend their existence, to be external to, and independent of, the sentient mind that perceives them; and we distinguish the acts themselves, of Sensa-

tion and of Thought, from any attributes of matter, simply because they are not objects of sense; and accordingly, we distinguish them from all attributes of matter, not in Man only, but throughout the whole of Creation; and say, without hesitation, that every living being in which we judge that any act of Sensation or Thought takes place, *i. e.* that every Animal, is the residence of Mind.

When we speak, as physiologists generally do, of Sensation and Thought as functions of the Nervous system, it must be obvious, from what has now been said, that we use this term Function in a sense somewhat different from that in which we apply it to other textures or organs of the body; because, in all other instances, we apply the term to a change which may be made, in some way or other, perceptible to our senses; and the changes now in question are, from their very nature, imperceptible to our senses; and known to each of us, as existing in any living body but his own, by inference only.

When we say that Sensation and Thought are Functions of the Nervous System, we mean only that this system *furnishes the conditions* under which Sensation and Thought in the living body take place; and when we say that Instinctive and Voluntary Motion are, in part, functions of the Nervous System, we mean that this system *forms the Medium*, through which certain acts of mind, called Instincts and Volitions, are enabled to excite certain muscular contractions.

How it happens, that, under certain conditions of the Nervous System, in the living body, the different mental phenomena should be connected with it, we have no reason to expect that we ever shall know. When we examine the structure of the Brain, we see nothing which could have led us to anticipate, that it would be the residence

of Sense or of Intellect; and when we reflect on the powers of the human mind, and compare them with the indications of a Superior Intelligence which we see around us in the world, it appears inconceivable to us that they should be linked with the existence, grow with the growth, and change with the changes, of a piece of soft white matter. But in all other inquiries into the works of Nature we meet with ultimate facts, that are equally beyond our comprehension.

The true objects of this department of Physiology are only these,—to distinguish and arrange the different Mental Phenomena themselves; to ascertain the conditions in the state of the Nervous System, on which their manifestation depends; and to trace the effects on the various functions of the body, which result from them.

II. Sensations may be divided into those which are felt in consequence of impressions made on individual organs only, such as Light and Colour, Smells, and Sounds, called the Higher or Special Sensations; and those which are felt are pretty generally over the body, as Touch, Heat, Cold, Pain, to which the name of Common Sensation is given. Acts of Thought, again, may be divided into those which not only proceed from no immediate cause, but are followed by no immediate effect, external to the mind itself,—such as Recollections, Judgments, Acts of Imagination;—and those which are immediately followed by changes in the body. Of this last class, Instincts and Volitions, which are uniformly followed, in the natural state, by contractions of certain muscles, are the most unequivocal instances; but certain Sensations and Emotions are likewise naturally followed, either by muscular contractions, or by alterations in the circulation,

or in the secretions of various organs. We do not enter as yet into any details regarding these mental acts ; but the distinctions now stated are easily recognised.

That the Nervous System is essentially concerned in, or furnishes necessary conditions to, all these phenomena, we conclude from the following facts :

1. It is shewn by unequivocal experiments, and by the uniform result of observations on the human body, that Sensation in every part of the body, and the effects of Instinctive or Voluntary efforts on the muscles which these affect, are essentially dependent on Nerves distributed to those parts, and are prevented from taking place, when the communication of these nerves with the cerebro-spinal axis is interrupted, by compression or destruction of the nerves. How the different portions of these nerves are concerned in, and how far the Spinal Cord and Brain are essential to, these functions, will be considered afterwards.

2. Although we cannot say that the indications of mental phenomena, in organized beings, coexist exactly with the existence of a Nervous System, yet in general, throughout the animal kingdom, and especially in vertebrated animals,—which have a spinal cord, similarly formed as the human, and organs corresponding to brain and cerebellum, —the more complex structure of the Nervous System is proportioned to the greater perfection in which the acts of Sensation and Thought take place ; and the more complex structure of the Brain proper in particular, to the greater intelligence of the animal.

3. All Sensations, Thoughts, and their effects on the body, are liable to alteration from injury or disease of the nervous system, especially of the Brain and upper part of the Spinal Cord; and there are certain injuries of these parts, to be afterwards specified, which never fail to put a

stop to all indications of the most important mental phenomena.

4. There is no other texture, upon which the mental phenomena shew any dependence,—any alterations which they undergo, in consequence of injury of other textures, being always referable to an injurious influence transmitted, directly or indirectly, from those other textures to the nervous system.

5. The changes produced in different organs of the body, by the different acts or affections of the mind, correspond very nearly to the changes which are observed in these organs (*e. g.* muscles, voluntary or involuntary, glands, &c.), from the physical injuries of the Nervous System already considered.

We can have no doubt that the Nervous System is fitted for the purposes which it serves in regard to the mind, by the peculiar Vital Properties with which we have found that it is endowed; and which are so far exemplified by the effects of physical irritation or injury above noticed. But these vital properties are known to us only by their effects; either on the mind, on the one hand, or on the other bodily organs, on the other.

III. Certain general conditions may be stated, as essential to the existence of these vital properties in all parts of the nervous system.

1. The most important is, the circulation of Arterial Blood through the nervous matter,—a condition necessary for all functions, but the interruption of which is more speedily injurious to this than to any other: and the necessity of which condition will appear distinctly when we treat of Respiration.

2. Various facts show, that any sudden alteration of the Pressure to which the nervous matter is subjected, is

frequently followed by diminution or suspension of all the animal functions; as, *e. g.* in the case of insensibility, produced by bleeding in the erect posture; or by tapping, without bandaging the abdomen, &c.; and again, in the case of any such mechanical compression of the brain as shall specially affect the medulla oblongata. It seems probable, that to the sudden alteration of pressure on the nervous substance, we should refer the fact, that drawing off the small quantity of fluid that exists, in living animals, beneath the arachnoid and in the ventricles, enfeebles or suspends the animal functions.*

3. Various facts pretty clearly indicate, that the Nervous System is not passive during the performance of any of the animal functions connected with it, but undergoes changes in which some (although imperceptible) Movement of its particles is probably concerned. Of this kind are the following:

An impression from an internal physical cause made on a part of the Nervous System, will sometimes excite the same kind of sensation as an external impression on certain organs of sense. Again, the sensation produced by an impression on an organ of sense, lasts longer than the application of the external cause, as is particularly obvious in regard to the sensation of Light, and we shall afterwards find that there is good evidence of a perceptible interval elapsing between an impression being made on an organ of sense, and the consequent sensation being felt. Again, sensations which have forcibly engrossed the attention, are often irresistibly obtruded in a less degree of intensity, especially during darkness and silence, long after their causes have been removed.

Farther, it may be observed, that excessive exertion of any of the animal functions induces morbid phenomena,

* Magendie, Journal de Physiologie, t. vii. et viii.

which indicate derangement of the circulation in the parts of the nervous system most connected with them ;—and that both Sensations and Volitions, as connected with the Nervous System, present many striking analogies to the phenomena of muscular contractions ;—that they undergo changes from repetition and habit, similar to those formerly noticed in contractile parts ;—and, in particular, that the nutrition, of the nerves of sense at least, is increased by their habitual employment, and diminished by their inactivity ;—that these functions require, equally as most muscular contractions do, intervals of relaxation or suspension, which they enjoy during sleep ;—that they are gradually altered, nearly in the same way as muscular contractions are, in the progress of life ;—and that various poisonous or medicinal substances taken into the circulation, affect the animal functions in a way analogous to that in which they affect involuntary muscular contractions.

IV. It is now well ascertained, not only that the Vital Properties, which shew themselves on physical irritation of nervous matter, vary in different parts of the system, but that the Mental Phenomena, which are connected with different parts, are quite distinct ; and considerable progress has been made in the *appropriation* of the parts of the Nervous System to the different mental phenomena. The parts which are appropriated to Sensation, and to Instinctive or Voluntary Motion, are nearly ascertained ; and the statements to be made on that subject may be introduced here. Those appropriated to other mental acts are less clearly distinguished, and what is known as to them will appear in the account to be given of the functions in which these acts are concerned.

1. As to the office of *Nerves* in Sensation and Volun-

tary Motion,—it is known, as already stated, that they are essentially concerned in these functions; but it is also ascertained that there are *no sensations*—not even such as are common to all parts of the body—which are *felt in all nerves; i. e.* in consequence of impressions made on all nerves; but that there are, in all parts of the body, certain nervous fibres or filaments destined to sensation, and others incapable of exciting sensation.

It has appeared, from the numerous experiments, first of Sir C. Bell, and since of Magendie, Beclard, Mayo, Muller, Panizza, and many others,—confirmed in a great measure by observations of cases of disease in the human body,—that it is by irritation of the posterior roots of the spinal nerves, and posterior surface of the cord, almost exclusively, that indications of pain (*i. e.* of common sensation) are excited; and that it is by section of these roots that insensibility of the parts supplied by these nerves is produced. And on the other hand, as it is by irritation of the anterior roots of the spinal nerves, and anterior surface of the cord, that muscular contractions are chiefly or almost solely excited, so it is by section of these roots that muscles are palsied, *i. e.* that voluntary efforts are rendered ineffectual for their excitation. Hence it appears, that it is only in consequence of different filaments of nerves, with different endowments, being bound up in the same sheath after they leave the spinal canal, that these spinal nerves generally appear to minister both to sense and to voluntary motion.

Again, similar experiments and observations shew still more clearly, that those of the cerebral nerves which were mentioned as capable of exciting muscular contractions when themselves irritated (the 3d, probably the 4th, the anterior branch of the 5th, the 6th, Portio Dura, and 9th), are the motor nerves, by which the muscles of the eye-

ball, lower jaw, face, and tongue, are moved in obedience to the will; and that the ganglionic portion of the 5th is the sensitive nerve, which gives, exclusively, common sensation to the face, eye-ball, mucous membrane of the nose, mouth, and tongue.

This great sentient nerve is easily shown to be in communication with the posterior portion of the spinal cord; and several of the motor nerves above mentioned, certainly communicate with its anterior columns. The intricacy of the course of the nervous filaments, above the decussation at the corpora pyramidalia, makes it impossible to give a decided opinion as to the connection of the 4th, the motor part of the 5th, and the Portio Dura of the 7th, with those columns, although it is very probable that such connection exists. According to Sir Charles Bell,* the 3d and Portio Dura are connected at their roots, both with the anterior columns, and with the posterior portion of the lateral, which he now regards as the sensitive columns.

The different branches of the 8th pair have been often thought to be possessed both of sensitive and motor powers; but the experiments of Dr Reid† have unequivocally shewn, that the distinction of sensitive and motor is kept up in them, equally as in the roots of the spinal nerves,—the glosso-pharyngeus being sensitive,—the pharyngeal and œsophageal branches of the par vagum motor,—the superior laryngeal sensitive,—the inferior laryngeal or recurrent, and the spinal accessory motor, and the pulmonary and gastric branches sensitive.

As these nerves arise one above another from the lateral columns, and from the posterior portion of the spinal cord, and as the spinal accessory, at least, arises much

* Edin. Phil. Trans. 1838.

† Edin. Med. and Surg. Jour. 1838.

lower down than the part where any of the filaments of the anterior columns have been found by Mr Solly to dip backwards to its posterior surface, it is obvious, from these facts, that there are motor nerves set on the posterior or sensitive portion of the cord, as well as its anterior or motor portion; and this is an important fact, in accordance with others formerly stated, as shewing that motor nerves possess the power of exciting muscular motion in themselves, and do not derive it from the parts of the brain or spinal cord, with which they are in connection.

It is also highly important to observe, that the motions excited by the pharyngeal and œsophageal portions of the par vagum, in the human body at least, are not under the influence of the will; and the same observation applies in all probability (as will appear when we treat of the Nerves of Respiration) to the spinal accessory. It may be conjectured, therefore, that all these are set upon the sensitive columns of the spinal cord instead of the motor columns, because they are intended to obey sensations, not efforts of the will. But in order to confirm this conjecture, it would be necessary to ascertain that the recurrent nerve, which is certainly under the influence of the will, is connected, at its origin in the medulla oblongata, with the anterior columns, as well as with the lateral. The statements of Bellingeri and others have been adduced to shew, that the appropriation of the nervous filaments arising from the different surfaces of the spinal cord to motion, and to sensation, is not absolutely exclusive; but, according to the recent observations of Muller*, in the case of reptiles, and of Panizza, both in

* See Muller in Annales des Sciences Naturelles, t. xxiii.; and Physiology by Baly, p. 642, et seq.; and Review of Panizza's Researches on the Nerves, in Edin. Med. and Surg. Journal, 1836.

reptiles and mammalia, the appropriation of the posterior and anterior roots of the spinal nerves to sensation and to voluntary action respectively, appears to be complete and exclusive.

While it thus appears that the sensations common to all parts of the body are felt only through certain of the nerves, it is also certain that the peculiar sensations which have special organs appropriated to them, Smell, Sight, and Hearing, are felt only through their peculiar nerves, the 1st, 2d, and portio mollis of the 7th (or a part thereof); and even, from the experiments of Magendie, that these nerves are incapable of exciting common sensation; their sensibility being confined to the qualities of external things to which they are appropriated, and the common sensations of the organs in which they are found depending on the 5th pair.*

The peculiar sensations of these special organs have been found to be impaired by injury of the branches of the 5th nerve entering them; but this does not prove, that the injuries of that nerve have more than an indirect influence on these sensations, perhaps dependent on the alteration which its injury produces on the nutrition of these parts (see p. 190). It has been thought, that in some animals the organs of some of the peculiar senses are supplied from the 5th pair exclusively, and the peculiar sensations felt only through them; but this observation is probably erroneous.†

It is still somewhat doubtful how far the ganglia and plexuses of the nerves are concerned in Sensation and in Voluntary motion. The absence of ganglia from the nerves

* Journal de Physiologie, 1824 and 1825.

† See Serres, Anat. Comparée du Cerveau, Art. Nerf Trijumeau; and Geoffroy St Hilaire, sur la Vision de la Taupe; Revue Médicale, tom. iv. p. 138.

of the special senses,—their absence from the sensitive nerves of fishes,*—and the obscure indications of sensation given by the sympathetic nerve and its ganglia when irritated, shew pretty clearly, that the ganglia on the posterior roots of the spinal nerves are not essential to their power of exciting sensation; and it will afterwards appear probable that they are more connected with the power exercised by these nerves over the capillary circulation and the organic functions. The most important facts as to the use of the plexuses of the cerebro-spinal nerves (*e. g.* of the axillary plexus and the similar arrangement in the sciatic nerve) are those stated by Panizza† and by Cronenberg;‡ from which it appears that several of the nerves entering a plexus may be divided without the *loss* of any one of the motions of the limb supplied by it, all the motions being merely *enfeebled*. This is quite in accordance with the speculation of Monro§ on the use of a Plexus; but he concluded, that the plexus is important only as a security against the effects of injury; whereas the more correct inference seems to be, that by this arrangement the will can act, when occasion requires, with more energy, because from more points of the spinal cord on any one of the nerves that emerges from a plexus than it could otherwise have done; and that the voluntary impulse given to any movement effected through a plexus, may be raised at pleasure in a greater degree than that given to a movement effected through a single nerve. This agrees perfectly with the intimations of our own consciousness as to the movements of the limbs

* See Swan's Comparative Anatomy of the Nervous System.

† See Edin. Med. and Surg. Journal, 1836.

‡ Plexuum Nervorum Structura et Virtutes. Berlin 1836, p. 141, *et seq.*

§ See Observations on the Nervous System.

as compared with movements of the trunk of the body; and probably in like manner the use of the plexus, as to the sensitive nerves, is to give precision and distinctness to the sensations produced by impressions on all the different points of the extremities of these nerves.

2. There is some difficulty as to the necessity of the intervention of the Spinal Cord and Medulla Oblongata in Sensation and Voluntary Motion. It has generally been observed, in experiments on animals, and in cases of injury in the human body, that destruction of the spinal cord, above the origin of a nerve, equally destroys sensation and voluntary motion in the parts supplied by that nerve, as section of the nerve itself; and hence it has been concluded, that some change is necessarily propagated *upwards*, along the nerve and spinal cord, to the brain, in the case of Sensation, and *downwards* along the spinal cord and nerve, from the brain, in the case of Voluntary Motion.

But it has been observed by different physiologists, Haller, Whytt, Legallois, Mayo, &c. and more lately and particularly by Flourens, by Dr M. Hall, and Mr Grainger, that even in warm-blooded animals, after the medulla oblongata or spinal cord has been divided, certain movements of the inferior extremities have been made on irritation of the skin of these parts. These have been generally thought to indicate some remains both of sensation and of voluntary power in the parts thus severed from the brain; in the cold-blooded animals, it has been generally admitted, that the Nerves and Spinal Cord suffice for giving pretty obvious indications, both of sense and voluntary motion, when separated from the Brain and Cerebellum; and this opinion, although opposed to that of Flourens, was strongly stated by Cuvier, in his Report on the Experiments of that physiologist, as the proper infe-

rence from them. In the human body one case of division of the spinal cord by wound, and several of more or less complete interruption of its continuity by disease, have been recorded, in which absolute loss of sense, and of voluntary power, were not observed, and were thought not to have occurred before death.*

These observations have led physiologists, at different times, to very different speculations. Some have thought that the proper inference from them is, that the changes essential both to sensation and voluntary motion, may be truly *confined to the nerves*, and only *liable to a noxious influence*, transmitted downwards, from injury or disease of the Spinal Cord or Brain; which noxious influence, although it very generally follows, may not necessarily follow, such injury or disease.†

But the following considerations, long ago urged on this point by Haller,‡ seem sufficient to shew that the common opinion of the *transmission of some change*, through the spinal cord, *upwards* to the brain in sensation, and *downwards* from the brain in voluntary motion, is well founded.

First, In the common case of loss of Sensation and voluntary power after section of the spinal cord, the lower segment of the cord, and nerves arising from it, are still perfectly capable of exciting contraction of the muscles of the lower limbs, when themselves physically irritated; which implies, that the loss of voluntary power, after the section, is not because the nerves of the lower limbs cannot act on the muscles, but because the brain or upper

* See Desault, Journal de Chirurgie, t. iv.; Ollivier sur la Moelle Epiniere; Velpeau in Archives des Medecine, 1825.

† This was stated, only however as a conjecture by the late Dr Gordon in his Lectures on Physiology.

‡ Elemen. Physiol. t. iv. p. 295, *et seq.*

part of the spinal cord cannot act on the nerves; and, therefore, that when the communication is entire, the brain, or something within the cranium, does act on the nerves.

Secondly, After division or disorganization of the spinal cord, as after amputation of a limb, pains are often felt, distinctly referred to the parts below the section; which implies, that the usual sensations of these parts had been dependent on changes extending at least as high as the section. Farther, at the will of the person, in such cases, the usual effort to move the limb is made, and is effective on such muscles, supplied from above the section, as used to be associated with those now palsied; which implies, that the effort which was wont to be effectual on the whole of these muscles, had been attended by a change in the parts of the nervous system higher than the section, which had been transmitted downwards.

As these statements apply to sections in *any part* of the Spinal Cord, it can hardly be doubted that the propagation or transmission of a change along the nervous matter, to and from the brain, in the ordinary case of Sensation and Voluntary Motion, does take place; but it does not follow from this, that no degree of sensation, or of voluntary action consequent on sensation, can possibly take place when the nervous communication with the brain is in any manner interrupted. In some of the lower animals (chiefly cold-blooded), there can be no reasonable doubt of the possibility of sensation being felt, and a certain degree of voluntary motion being performed, in parts cut off from communication with the brain. In most of the cases of the kind recorded as having occurred in the human species, inaccuracy of observation, before or after death, may be suspected; but it is also possible, either that a less degree of the mental acts may be connected with the inferior portions of the spinal

cord; or that absolute continuity of nervous substance may not be essential to the transmission of nervous agency; and the latter supposition is supported by the fact of that agency affecting blood within vessels; and by the effects of section of a nerve, when the cut ends were laid in contact, having, in various instances, appeared less injurious than the effects of section, with loss of substance.*

On the other hand, it has been strongly urged of late years, by Flourens in France, and by Dr M. Hall and others in this country, that these movements of distant parts, excited by irritation of sensitive nerves in animals, when the medulla oblongata or spinal cord has been severed from the brain and cerebellum, do not indicate sensation, but result only from physical impressions made through sensitive nerves on the spinal cord, and acting thence on motor nerves, in virtue of what the latter author has called its Reflex Function—a function, the exercise of which is connected in the natural state with Sensation, but not necessarily dependent upon it.

It is certainly possible, and indeed has been already stated as a fair inference from facts observed in the human body, that impressions made on sensitive nerves in the living state, but when the power of sensation is suspended, may so imitate those changes in them, which in the natural state are attended by sensations, as to produce some of the muscular contractions, by which these sensations are generally succeeded and indicated; and all that can be certainly inferred from the facts in question is, that it is in the spinal cord that this *crossing* of the action excited in the nervous matter, from the sensitive to the motor filaments, takes place. But there is no distinct evidence that *regular combinations and successions* of muscular movements can be effected in distant muscles

Wilson Philip, Philosophical Transactions, 1822.

by impressions on sensitive nerves, without sensation intervening as part of the chain of events; and facts to be afterwards stated in regard to movements of this class (commonly called sympathetic movements), under the head of Respiration, Deglutition, &c. seem sufficient to shew, that in the natural state, and for useful purposes, sensations do intervene, and that their existence may be inferred from such sympathetic movements. What is lost by cutting the medulla oblongata and severing the spinal cord from the brain, as in the experiments of Flourens, probably is, as stated by Cuvier, not the faculty of sensation, but the recollection, even the instant after, of sensations that have been felt.*

3. If this last inference is admitted, we may regard it as ascertained, that no part of the Brain, higher than the Corpora Quadrigemina, nor of the Cerebellum, is essentially concerned in Sensation. All the parts superior to this have been frequently injured, by many physiologists, in warm-blooded animals; and have been wholly removed, even in warm-blooded animals, by Du Verney, Chirac,† Lorry,‡ Legallois, Flourens, Fodera, and Magendie; and, if the remaining nervous matter was kept free from compression, such movements of distant parts, on irritation of the skin, as are usually thought indications of sensation remained; and such Instinctive or Voluntary efforts as seemed to be made, were still effectual in exciting muscular contractions of all parts of the body.

4. It has been conjectured, particularly by Mr Solly and Mr Grainger, that the grey matter of the brain and spinal cord is essentially connected both with sensation

* See Cuvier's Report on Flourens' Experiments, in the Recherches Experimentales of the latter author.

† Phil. Trans. 1697.

‡ Mem. presentées à l'Acad des Sciences, t. iii.

and voluntary motion ;—the former they regard as the "source of power" in the strictly voluntary movements, the latter in the movements ascribed to the Reflex Function of the Spinal Cord. But if by the phrase "source of power" it is meant, that some influence or energy passes from these masses of grey matter to every motor nerve which excites a muscle, two facts, already stated, appear sufficient to set aside that theory : 1. That after a motor nerve has been cut off from all communication with the brain and spinal cord, and then irritated by galvanism until its power of exciting motion appears to be exhausted, it regains it completely without that communication being restored ; and, 2. That in experiments by Magendie, the central portion of the spinal cord was repeatedly crushed without any obvious effect either on sensation or motion. And it will afterwards appear, that other purposes seem to be served in the animal economy by portions at least of the grey nervous matter, connected indeed with the excitement of mental acts, or with their effects on the body, but not essential, either to sensation or voluntary action.

It appears to be the proper inference from these experiments, that if we regard the spinal cord as reaching to the Corpora Quadrigemina, and giving origin to all the nerves (see p. 174), we are to attribute to it, and to the nerves arising from it,—but especially to its highest portion, the medulla oblongata, and fibres extending thence to the crura cerebri,—all the physical conditions that are necessary, in order that Sensation may be felt, and that Voluntary efforts may excite muscular contraction ; the mental stimulus of Volition being just on the same footing, in regard to muscular contraction, as a physical stimulus applied to the medulla oblongata. (See p. 185.)

Accordingly, instances have been recorded by Mr Law-

rence,* and others, of infants of the human species, born alive, apparently capable of sensation, and of certain instinctive actions, in whom the nervous system terminated at the Tuber Annulare.

It has also been distinctly proved by experiments by Legallois and Flourens, that two of the sensations which may be called peculiar and special, those of the eye and of the lungs, are necessarily connected only with those portions of the contents of the cranium which lie close at the origins of their nerves.

It will appear afterwards, with what intentions, as regards sensation and voluntary motion, the brain and cerebellum are superimposed on the spinal cord. It will appear that they are useful, not in order that Sensations may be felt, but that they may be remembered, and availed of for useful purposes; not in order that Volitions may act as stimuli on muscles, but that they may act on them at the right times, and in the requisite variety of combinations and successions.

The facts now stated enable us to understand, without difficulty, so far as mere sensation and the power over the muscles are concerned, how it should happen that some injuries or diseases of the brain proper, or cerebellum, should affect these functions materially, and others not at all; because all injure these functions only in so far as they affect the medulla oblongata; and it is easy to understand, that the effect of some such diseases or injuries may extend downwards to the medulla oblongata, and that of others not. And this is well illustrated by Fodera's experiments on the comparative effects of *lateral* and *vertical* compression of the brain or cerebellum,† the former seldom affecting the functions of sense and

* Medico-Chirurgical Trans. vol. v.

† Journal de Physiologie, t. iii.

voluntary motion, and the latter always producing either convulsion or coma.

V. It is necessary, before proceeding to the functions of Respiration and Digestion, to distinguish more accurately the different kinds of mental acts, which operating through the spinal cord and nerves, excite various combinations of muscular contractions.

1. Voluntary motions are those which are not only preceded by a mental act, and attended by a sensation that informs us of their performance, but accompanied besides by a conviction, that we may perform them or not as we please. This conviction is the characteristic of that mental act which we call Volition. How this notion is formed, and whether or not it may be deceptive, we do not now inquire; its existence is all that concerns us at present.

2. There are likewise in the healthy state, motions of voluntary muscles which are quite involuntary, of the performance of which we are conscious, but which we have no direct power of controlling, and often strive in vain to counteract or conceal. These, on examination, appear always to be preceded, and we have every reason to think that they are caused, either by Sensations, as in the case of Sneezing, Coughing, Vomiting, &c., or by those mental acts or affections which we call Emotions, as in the case of Laughter and Weeping.

3. The former class of actions are divided into those which are more strictly Voluntary, and those which are properly called Instinctive. The distinction of these lies in this circumstance, that in the former case, we have a distinct object in view; our actions are not only prompted by an act of which we are conscious, but directed to an end which we desire; but in the latter case our actions

are consequent indeed on a sensation, but prompted by a blind impulse, which acts even when the consequences that are to follow from the action are unknown or disregarded;—as in gratifying the appetites, guarding the eyes from danger by closing the eyelids, or the body from falling by throwing forward the hands.

The instinctive actions are closely connected with the motions that proceed directly from sensations on the one hand, and with the strictly voluntary motions on the other. In the adult human being it is hardly possible to distinguish them from movements that have been prompted by reason, and become habitual; but in the infant, and in the lower animals, they are easily distinguished, chiefly by two marks, 1*st*, That they are performed always in the same way; whereas actions that are strictly voluntary and prompted by reason, although directed to the same ends, vary considerably in different individuals. 2*dly*, That, however complicated the movements, the truly instinctive actions are performed equally well the first time as the last; whereas even the simplest of the strictly voluntary movements require Education.

The phenomena and effects of Instinctive and Voluntary motions will require a separate consideration afterwards; but it was necessary here, as a preliminary to the subjects of Respiration and Digestion, to specify the different modes in which, through the intervention of mental acts, muscular contractions may be excited in the living body.

These two functions are common to the whole animal kingdom, and their purpose is to maintain the requisite quantity and vital power of the nutritious fluid, which is essential, as was already stated, to the vital powers of the moving solids, and to the vital action of all other parts, and especially of the Nervous System.

These purposes are fully accomplished in vegetables, and in the fœtus *in utero*, before there are any indications of sensation ; and even in the adult animal a great part of the changes, which come under the heads of Respiration and Digestion, belong strictly to the Organic Life. But in all animals the reception of food into the digestive organs, and in all vertebrated animals, and many of the inferior orders, in the adult state, the reception of air into the respiratory organs is accomplished, by movements which are excited through the intervention of Sensations and of Instincts or Volitions ; and therefore the commencement of the processes of Respiration and Digestion in them belongs to the province of Animal Life, and may be shewn to be dependent on the Nervous System.

CHAPTER X.

OF RESPIRATION.

The arterialization of the blood by exposure to air is of such importance in the animal economy, that in man, and the animals the most analogous to man, its interruption for a few minutes is fatal. In comparing the different classes of animals, especially the great divisions of Warm-blooded and Cold-blooded, and still more remarkably, in comparing the different states of those animals which hybernate, or are subject to periodical torpor, it is observed that the strength and rapidity of vital contractions, the energy of the functions of the Nervous System, the elevation of the animal heat, and, in general, the intensity of all the vital functions, are nearly in proportion to the degree of action that takes place between their blood and the air.

But it is not yet fully ascertained, whether this action is merely of the nature of excretion from the blood, of something which would be noxious if retained, as is the case with the discharges of bile and of urine ; or whether the oxygen added to the blood from the air, assists in qualifying it for its office in the system : and therefore it may still be doubted, whether the intensity of the vital functions, that goes along with the high degree of this action of the atmosphere on the blood, is to be regarded as its cause or its effect.

One chemical change on the air is seen from the action of the fluids of all living beings, viz. the disappearance of

more or less of the oxygen, which forms about 20 per cent. of its constitution, and the increase of its carbonic acid, which forms less than 1 per cent. of it; and the volume of the carbonic acid added has always appeared to approach, and in many cases to equal, the volume of oxygen lost.

But in vegetables, when living and exposed to light, another chemical change is effected on the surrounding air, viz. the removal of part of its carbonic acid, and the substitution of oxygen, or what is usually called purification of the atmosphere.

It has not yet been ascertained, whether this purifying influence of vegetables does or does not exceed the vitiating influence of the exhalation or formation of carbonic acid, which is likewise seen in them; but it is certain that the whole effect of animal life on the atmosphere is vitiating, *i. e.* to cause addition of carbonic acid to it; and other processes, always going on at the earth's surface, have a similar effect; and yet the whole quantity of carbonic acid in the atmosphere is not found to increase. There must, therefore, be some purifying cause continually in operation to compensate for the continual vitiation; and we know of none acting on a large scale, except the influence of living vegetables.

Farther, it appears certain that vegetables may grow, and the quantity of carbon in them gradually increase, when they are supplied with air and water only, and can derive no supply of carbon from the earth.*

These circumstances render it highly probable that living vegetables, on the whole, decompose more of the carbonic acid of the atmosphere than they form; and therefore both purify the atmosphere, and derive part of their nourishment from it.

* Saussure, Recherches Chimiques, p. 50, *et seq.*

The facts which favour this opinion have been ingeniously and judiciously connected by M. Adolphe Brogniart,* with observations made on the remains of organized substances on the crust of the earth, which show that an extensive vegetation must have existed, at a time when there were few or no animals, and that subsequently many cold-blooded animals inhabited the earth and sea, before there were any warm-blooded animals. If we suppose the atmosphere to have contained originally a much larger proportion of carbonic acid than now, it may be inferred from what has been said, that it would enable vegetables to grow before any carbonaceous soil existed, and would be gradually purified by their growth; and the degree of vitiation which would result from the respiration of the cold-blooded animals, might probably be more than compensated by the purifying influence of the vegetables. After the purification had been carried to a certain length, the atmosphere would become fitted for the respiration of warm-blooded animals, which require a fuller supply of oxygen, and exhale carbonic acid more abundantly; and from the time of their creation, it would appear that the processes which purify, and those which vitiate, the atmosphere, are pretty nearly balanced.

But whatever the provisions may be, by which the average purity of the atmosphere is maintained, notwithstanding the continual additions of carbonic acid which it receives from the respiration of animals, the importance of the process to animal life is illustrated by the adaptation of the respiratory organs, in different animals, to the degree, and the mode of action, of the air on their fluids. This adaptation is determined chiefly by the following conditions.

1. By the degree of density or solidity, and complica-

* Annales des Sciences Naturelles, tom. xv.

tion of the textures composing the animal. When the structure is simple, or the materials light and porous, whether the respiration is atmospheric or aquatic, air, or water containing air, is admitted freely into all parts of the animal, and no part of the body is appropriated to the function. This is the case in Zoophyta and Insects; in the first of which classes the respiration is cutaneous, *i. e.* water containing air acts on all the surfaces of the animal; in the last, it is tracheal, *i. e.* air is admitted by canals destined for the purpose into all parts of the body, so as to come every where into contact with the nourishing fluid. But where the structure is complex, and some of the textures dense and impervious to air, a separate respiratory organ, and along with it, as before observed, a circulating system, are required.

2. Where these organs exist, their nature is determined by two conditions,—*first*, by the amount of vital energy which the animal is to possess, and proportional amount of action of the air on the blood, for which provision is to be made; *secondly*, by the medium in which it is to exist. When it inhabits air, and is warm-blooded, it breathes by lungs, and has a double circulation, *i. e.* all its blood, after completing the circulation through the body, is sent to the lungs. This is the arrangement in the Mammalia and Birds. When it inhabits air, and is cold-blooded, it breathes by lungs, but has a single circulation, *i. e.* sends only part of its blood to the lungs, and that part is mixed with what returns from the rest of the body. This is the mode of respiration of Reptiles. When the animal is to inhabit water, it acts on the air contained in that water, by gills or analogous organs. But as this action is necessarily slight in comparison with that which takes place in lungs, the whole blood may be sent to the gills, and the animal nevertheless be cold-blooded. This is the

mode of Respiration in Fishes, and most of the Mollusca, the Crustacea, &c., and of the Batracian Reptiles in the first stage of their existence.

The smaller number and larger size of the particles of blood in cold-blooded animals, are likewise adapted to the less degree of action which is to take place between it and the air; and various additional provisions, adapted to the circumstances of different classes of animals, farther illustrate the same principle. Thus birds, in which there is occasion for great muscular energy, and therefore for a full supply of air, have not only lungs, but likewise tubes and cells, which admit the air into contact with their blood, in almost all parts of their bodies. Reptiles, which breathe by lungs, but are frequently under water, or in very impure air, have lungs provided with vesicles of such size as to serve as reservoirs of air for these occasions. On the other hand, certain fishes and crustaceous animals, which breathe by gills, but are often for some time in the air, have reservoirs of water for their gills to act on during the time of their abode in air.* Some of the warm-blooded animals which habitually dive in water, seem to be enabled to dispense with the inspiration of air, at these times, by the great quantity of their blood, and by the great size of their large veins, permitting it to accumulate there, when, in consequence of suspended respiration, it cannot freely penetrate the lungs.†

But in the Cetacea additional provisions have been ascertained to exist, which strikingly illustrate the mode in which Respiration will afterwards appear to influence the other functions of the body. Those animals are not provided, like the reptiles, with any apparatus which can

* Cuvier and Dumeril, Rapport sur le Mémoire de Audouin et Milne Edwards, Annales des Sciences Naturelles, tom. xv.

† Edmonstone, in Phil. Magazine, August 1827.

serve as a reservoir of air during their submersion, but their large veins being dilated into sinuses near the heart, and those leading from the liver being furnished with muscular fibres, the venous blood which necessarily stagnates (as will afterwards appear) on the right side of the heart during their submersion, is securely lodged and prevented from injuring the liver or other viscera. And again, their larger arteries, particularly those entering the nervous system, are so constructed (chiefly by subdivision, convolution, and reunion), that they must contain a much larger quantity of blood, moving more slowly, than in other animals. They will therefore serve as a *reservoir of arterial blood*, and when the supply of blood to them from the heart and lungs is suspended, their tonicity will necessarily force forwards that which they contain, and so keep up the vital action of the nervous system, and of other organs, for a certain length of time.*

In the human body, the mechanism by which the regular application of the air to the blood in the lungs is secured, is well understood; but there is still some difficulty as to the precise nature of the chemical change; and as to the mode in which the cessation of that change at the lungs affects the rest of the system.

I. The first step in the process, as taking place in the natural state, is a Sensation in the breast, felt when the chest is at rest, especially after expiration, caused by venous blood moving through the lungs, amounting quickly to extreme anxiety if not relieved, and uniformly prompting the complicated action of inspiration, by which it is

* See Sharpey in Fourth Report of British Association, p. 682. Houston in Fifth Report of Do., p. 81 of Trans. of Sections. Kiernan in Phil. Trans., 1833, p. 738; and Breschet in Annales des Sciences Naturelles, 1834, t. ii. p. 376.

immediately appeased. The influence of the sensation, in exciting the acts of respiration, even during sleep, and during coma, appears from the increased energy and frequency of these acts, which may be produced by any means of obstructing the free access of air to the lungs, and so augmenting the intensity of the sensation.* And other Sensations, particularly those caused by certain irritations of the nostrils, or by cold suddenly applied to the face or breast, equally excite the act of inspiration.

This action being, in the natural state, caused by a sensation at the lungs, is necessarily dependent, in the first instance, on the sensitive nerves of the lungs, and especially on those which most directly communicate between the lungs and the medulla oblongata, viz. the eighth pair. Accordingly, certain irritations of these nerves have been observed by Marshall Hall, Broughton, and others, to excite actions of inspiration (and also of deglutition); and after section of these nerves, the actions of Respiration, although not stopped (probably on account of the other communications, through the sympathetics and spinal cord, which the lungs have with the brain), are yet performed slowly, and, after a time, imperfectly. And the experiments of Legallois and Flourens have shewn unequivocally, that by injury of the part of the medulla oblongata, from which these nerves originate (and of that alone, of all the contents of the cranium), all attempts at inspiration are finally arrested; no doubt because a final stop is put to the sensation which prompts them.

The objects of the movements which the sensation excites are, to enlarge the cavity of the chest in all directions, and at the same time to hold open the passages by which the air is to enter it.

The cavity of the chest is capable of change of dimen-

* See Whytt on Vital Motions, sect. 8.

sion in all directions, in consequence of the diaphragm, which forms its lower boundary, being itself a moveable and contractile part, and in consequence of the ribs, which enclose a greater part of it, being so articulated with the spine, as to be susceptible of motion upwards and downwards.

The chest is lengthened in the act of inspiration, chiefly by the contraction and descent of the diaphragm, especially of its fleshy lateral portions, which, from being convex towards the chest, are then flattened, and slightly depress its central tendinous part. It cannot pull down the ribs, because they are fixed, at the moment, by the contraction of the intercostal muscles. But the elongation of the chest is partly also effected by the action of those muscles of the front and sides of the neck, which pull the highest ribs towards the neck and head.

The chest is rendered broader and deeper in the act of inspiration, by the elevation of the ribs; because these are both curved outwards, and sloped a little downwards; and therefore, when raised nearer to a right angle with the spine, enclose a larger space within the arches they form transversely, and also project, and push the sternum slightly forwards.

The elevation of the ribs is caused partly by the action of the two strata of intercostal muscles, because the lower ribs are more moveable than the higher, and therefore must be drawn towards the higher, when the whole of these muscular fibres contract; but the motion of the ribs, in inspiration, especially when forcible, is assisted by the action of the diaphragm forcing upwards the lower margin of the chest, at least when the abdominal viscera oppose much resistance to its descent;* and also by the com-

* See Magendie, Precis Elementaire. The protrusion of the lower margin of the chest, apparently by the action of the diaphragm, is

bined action of those muscles which draw the scapulæ towards the cervical vertebræ and head, and of those which draw the ribs towards the scapulæ.

The glottis is held open, during inspiration, by the action of the muscles connecting the arytenoid to the thyroid and cricoid cartilages. The nostrils are slightly expanded, in forcible inspiration, by the muscles attached to the alæ of the nose. The Velum Pendulum Palati is raised and stretched by its own muscles, when inspiration is made chiefly through the mouth; and the lower jaw is often slightly depressed by the contraction of the muscles between it and the os hyoides.

Of these muscular actions, those of the diaphragm and intercostals are probably all that are employed in healthy and easy respiration; and in various circumstances, when there is an obstacle to the action of one of these, that of the other is found to suffice; but when the sensation prompting inspiration is intense and long-continued, all the other movements take place simultaneously, and with perfect precision, independently of all experience. The force, rapidity, and frequency with which they are performed, are all under the command of the will, and they may even be performed in conjunction or separately, except when the sensation that prompts them is unusually intense, in which case it supersedes all efforts of the will.

The movement of Inspiration is immediately succeeded by that of Expiration, partly no doubt because of the natural tendency of muscular contraction to alternate with relaxation, but partly also because somewhat of the uneasy sensation in the chest is felt when we rest on an inspiration, and is relieved by expiration; probably in con-

very obvious in the deformed chests of rickety children, when affected with dyspnœa, and seems to be the cause of the great depression of the ribs at the sides of the chest in such children.

sequence of the motion thereby given to the air along the surface of the membrane, where the capillaries carrying the venous blood ramify.

The act of ordinary expiration hardly requires any muscular effort, but is the natural effect of the cessation of the contractions by which inspiration was effected. The state of the thorax, after an ordinary expiration, is that which is determined by the physical structure and properties of the parts, and the pressure of the atmosphere, and has therefore been called the natural state of the thorax ; and the return to that state, after the effort of inspiration is over, is produced by the elasticity of the parts which have been stretched by that effort,—of the lungs themselves, of the parietes of the abdomen, of the cartilages of the ribs, and more especially of the ligaments that connect the ribs to the spine.

But when the sensation caused by venous blood in the lungs is intense,—when certain other sensations in the trachea or bronchiæ, or certain emotions, are felt,—or when a certain voluntary effort is made,—the diaphragm and ribs are brought back to their position, after inspiration, with force and rapidity ; and, by a continuance of the same action, the thorax is contracted within its usual limits. This is done by a simultaneous contraction of all the abdominal muscles, which both pull down the ribs, and force up the abdominal viscera against the diaphragm ; and the descent of the ribs is farther aided by the contraction of those muscles which arise from the sacrum and vertebræ of the loins, and are partly inserted into the lower ribs.

The movements of inspiration and expiration take place, in the healthy state, about once for every four pulsations of the heart, and therefore, on an average, about eighteen times in the minute. They are variously modi-

fied, both at the command of the will, and in obedience to certain sensations and emotions, in the performance of different complex movements to be mentioned afterwards.

As the chief agents in ordinary inspiration are the diaphragm and intercostal muscles, so the Nerves chiefly employed in conveying the stimulus given by the sensation in the lungs, must be expected to be the phrenic (which arise chiefly from the third and fourth cervical nerves, and descend along the fore part of the chest) and the dorsal nerves. As the sterno-mastoid muscle assists in elevating the whole chest, the trapezius in fixing the shoulders, and the serratus magnus in drawing the ribs towards the scapulæ, it must be expected that nerves supplying these muscles will be concerned. As the glottis is held open by the crico-arytenoid and thyro-arytenoid muscle, it must be expected that the recurrent nerves of the eighth pair, which supply these muscles, will be concerned; and, as the levatores labii superioris dilate the nostrils, it must be expected that some of the fibres of the portio dura, which supplies these, will be concerned. Accordingly, it has appeared in many experiments and observations by Galen,* by Cruickshanks,† by Legallois, by Bell, by Magendie, and others, 1. That section of the phrenic nerve stops the actions of the diaphragm in inspiration; 2. That section of the spinal cord in the lower part of the neck stops the actions of the intercostal muscles; 3. That section of the spinal accessory nerve weakens those of the sterno-mastoid and trapezius; 4. That integrity of the nerve called external respiratory, which has similar origins to the phrenic, and supplies the serratus magnus, enables the actions of that

* See Haller, Elem. t. iii. p. 240.

† Phil. Trans. 1795.

muscle to go on, after the spinal cord has been divided in the neck; 5. That section of the recurrent nerves, or of the par vagum above their origin, prevents the free opening of the glottis;* and, 6. That section of the portio dura prevents the dilatation of the nostrils. The necessary agency of certain nerves supplying the other muscles concerned, *e. g.* the scaleni, lesser pectoral, levator and circumflexus palati, digastric, and genio-hyoid, &c. may be safely inferred.

Experiments on animals, and cases of injury or disease in the human body, have also very frequently shewn, that division of the dorsal portion of the spinal cord renders the movement of expiration feeble and ineffectual for many purposes to which it is commonly applied.

Both by experiments on animals, of the class Mammalia, and by cases of injury of the human body, it has been ascertained, that division of the spinal cord above the origin of the phrenic nerves, palsies all the respiratory movements of the chest, and so causes sudden death. In birds, where the muscles corresponding to the diaphragm are of little avail, and respiration is entirely dependent on motion of the ribs, destruction of the dorsal portion of the spinal cord is fatal as quickly, and in the same way. In fishes, on the other hand, where the organs moving the gills have all their nerves from the medulla oblongata, the injury which palsies their respiratory movements

* It was stated by Magendie, that the recurrent nerve moves those muscles only which open the glottis, and that the transverse and oblique arytenoid muscles, which close the aperture, are moved by the superior laryngeal; but the experiments of Dr Reid have shewn, that this latter nerve is purely sensitive (but, as being sensitive, intimately concerned in the act of coughing excited by irritation of the larynx), and that all the movements of the arytenoid cartilages are effected through the recurrent nerves. (Edin. Med. and Surg. Journal, 1838.)

must be as high as that part of the nervous system. But there is no injury, except that of the origin of the eighth pair, which instantly, and in all animals, palsies* the whole combination of respiratory motions; apparently because there is no other, which puts an end to the sensation which, in the natural state, is the common cause of them all.

It is supposed by Sir C. Bell, that the nervous fibres, which excite the different respiratory muscles in obedience to the sensations of the lungs, are distinct from those which move the muscles in obedience to the will; and that they excite and combine the respiratory movements, because they originate exclusively in the lateral columns of the spinal cord, from which the great sentient nerve of the lungs (viz. the eighth pair) also arises.

On this theory it may be observed,

1. That it is not proved, nor probable, that any such bond of union exists among the roots of the nerves which move the respiratory muscles, to the exclusion, first, of those branches of the par vagum which go to the pharynx, œsophagus, and stomach; and, secondly, of those branches of the cervical and dorsal nerves which go to the axillary plexus and to the arm.

2. That it appears certain, from facts to be afterwards stated, that the circumstance of two nerves having any such peculiar bond of connexion at their root, if it were proved, would furnish no adequate explanation of their acting in concert with, or in obedience to, one another.

There are, however, several facts to shew that there is some peculiarity, not yet understood, as to the transmission of the impulse which excites the act of respiration; as it originates at the posterior portion of the medulla oblongata, it is probable that it may pass down by the poste-

* Flourens, in Annales d'Histoire Naturelle, t. xiii.

rior, or sensitive, not by the anterior portion of the spinal cord; that the spinal accessory nerve and recurrent nerve may act in obedience to that impulse, connected with sensation, because they are set, wholly or partly, on that sensitive portion of the cord; that the portio dura acts in obedience to sensation as well as volition, because, according to Sir C. Bell,* it is set on both columns of the cord; and that the impulse acts from the sensitive portion of the cord upon the motor filaments of the phrenic, intercostal, and lumbar nerves, not by the anterior columns of the cord, but either through the posterior roots of those nerves, or, what is more probable, by crossing the cord transversely to each of their anterior roots. On this supposition, the impulse connected with the sensations of the lungs (and the same may be true of other sensations) will not be prevented from acting on the respiratory muscles, although the anterior motor columns and the cord be divided or destroyed by disease. Cases given by Sir C. Bell and others, in which the function of respiration continued, notwithstanding that one, or even both, of the anterior columns of the cord had lost all vital power, strongly favour this supposition, but experiments to confirm it are still wanting.

Even on this supposition, we cannot pretend to explain why the sensation caused by the venous blood in the lungs, should always act upon those nerves only, whereby it can excite that extensive combination of muscular movements, by which it can be appeased; but it is obvious, as Sir C. Bell observes, that in Man, as in other animals, where the provisions for the reception of air are partly dependent on the nervous system, the nerves and muscles employed for this purpose are "put under the guidance of a Sensibility, more certain and more powerful in its effects than the Will."

* Edinburgh Phil. Trans. 1838.

The lungs in the living and adult state, having air in contact with their inner surface only, are always distended somewhat beyond the dimensions which they assume when the pressure of the atmosphere is allowed to act on their outer surface also, as by puncturing the chest. When the chest is enlarged, the air which they contain is rarefied, fresh air enters by the trachea, by reason of its own gravity and elasticity, and the lungs are farther expanded. This expansion, when the motion of the diaphragm is free, is chiefly in the longitudinal direction ; so that the lungs slide on the pleura costalis.

When the access of air to the interior of the lungs, or of part of the lungs, is prevented, either by closure of the glottis, obstruction of one of the bronchiæ, or occlusion of part of the air-cells, although the usual effort be made, the movement of inspiration is wholly or partially prevented ; not because the air within the chest is a cause of that movement, but because the pressure of the air without the chest is an effectual obstacle to the movement, when no air is admitted into the interior to counterbalance it.

The passage of the air through the bronchiæ, and into the cells of the lungs, causes a gentle murmur, perceptible on applying the ear to any part of the chest where it is going on, but which is not perceived when the subjacent portion of lungs is impervious to air ; and is easily altered by disease either of the substance of the lungs, or of the bronchiæ of the part, especially by morbid effusions.

The reasons which have led several physiologists to think that the lungs are not merely passive in the acts of Respiration, are—1*st*, That after the chest has been fully opened, and all motion of the lungs on the principle of suction necessarily prevented, a little movement in them cor-

responding to the respiratory efforts has still been seen in living animals.* *2dly*, That the respiratory murmur is in some individuals observed to be subject to sudden changes, for which no causes appear so probable as partial vital contractions of the cells of the lungs, or smaller bronchiæ.† But if any action of this kind in the lungs themselves does accompany the respiratory movements of the parietes of the chest, it must be to a very small extent only, because exposure of the surface of the lungs to the atmosphere very speedily causes death by suffocation, *i. e.* by stopping the admission of air to the lungs.

From the experiments of Jurine, Menzies, Thomson, Gordon, and others, it appears that the average bulk of air entering the lungs at each ordinary inspiration of a healthy man, is about 40 cubic inches; and if there be 20 such inspirations in a minute, this gives 1,152,000 cubic inches of air, or about 666½ cubic feet, drawn into the lungs in a day. It appears also, that not more than one-eighth part of the air contained in the lungs is changed by each respiratory act, not less than 280 cubic inches probably remaining in the lungs at the end of each ordinary expiration.

It is a curious fact, lately ascertained by Purkinje and Valentin, and confirmed by Dr Sharpey, that currents, similar to those formerly mentioned as visible in the water adjoining many aquatic animals, (and particularly in that which is in contact with their organs of Respiration) may be seen on the mucous membranes of the air passages in animals of all classes, if immersed in water within a very short time after death.‡ But as these are seen

* Williams in Edin. Med. and Surg. Journal, vol. xix. p. 353.

† Laennec, Traité d'Auscultation, &c. tom. i. p. 188.

‡ Sharpey in Edin. Phil. Journal, vol. xix. and Art. Cilia in Cyclopædia of Anatomy.

equally on the mucous membrane of the genital organs, it is probable that their immediate object is the movement and regular removal of the mucus covering the membrane, rather than of the air passing over it. In this case, as well as in the case of the lower animals, the absolute dependence of the currents on the movements of the cilia seen to attend them, appears to have been too hastily assumed by several authors. In some instances at least it seems certain, that both the degree and kind of the movement connected with the vital changes in the respiratory organs, are inexplicable by the vibrations of any cilia that have been detected. It is certain that cilia must have a very particular form and mode of action, which has not yet been detected in them, in order that they may cause regular currents in a fluid, in which they are *wholly* immersed. And in conformity with this view of the subject, it is expressly stated by Muller that from studying these currents in the gills of the tadpole, he had satisfied himself that they are not the effect of agitation communicated to the fluid by any part of the body of the animal; and that he believes them to be the effect of the chemical changes, in the blood and in the air, which accompany respiration.*

Although little of the inspired air can pass, at each inspiration, into the minute bronchiæ, or cells of the lungs, yet as it is now ascertained, that gases placed in contact mutually penetrate each other according to a fixed law,†

* See addition made by Muller to the chapter on the effects of Respiration in the Blood, in Burdach's Physiol. by Jourdan, t. vii. p. 36. See also Raspail Chim. Organique, § 582, *et seq.* and Plate 6, Fig. 4.

† See Dr Mitchell on the Penetrativeness of Fluids, in American Journal of Medical Sciences, vol. vii.; Graham on the Law of the Diffusion of Gases in Edin. Phil. Trans. vol. xii.; and Stevens on the Blood, p. 72.

a rapid communication will necessarily take place between the contents of the larger bronchiæ and the minutest air-cells; and as it appears, likewise, that gases readily enter fluids, when brought in contact with them, and pass out of fluids when exposed to other gases, it is certain that, on simply physical principles, much interchange of the component parts of the blood and the air must be expected at the lungs.

II. The results of very numerous experiments on the changes effected on the Air by Respiration may be stated thus:

1. It appears from the experiments of Edwards and others, that a slight and variable diminution of the whole bulk of the air in which an animal breathes, even in ordinary circumstances, generally takes place. When the air becomes vitiated, and the breathing difficult, this diminution is greater, probably because the lungs, in these circumstances, are not completely emptied. The proportion of oxygen in air that has been breathed is ascertained, and compared with the ordinary proportion, by different eudiometers; and the proportion of carbonic acid by exposing the air over mercury, in a graduated tube, to aqua potassæ, which absorbs the acid.

2. The proportion of azote, in air that has been breathed, has appeared in many experiments to be the same as in the atmosphere in general, and therefore it has been supposed that this gas is neither absorbed nor exhaled at the lungs; but Dr Edwards' experiments, coinciding with those of several other physiologists, have shewn, that on some occasions, there is a small increase, and on others, a small diminution, of the azote of the air breathed;* and experiments made by Allen and Pepys

* De l'Influence des Agens Physiques sur la Vie, p. 420, *et seq.*

have shewn, that when oxygen, or a mixture of oxygen and hydrogen, is breathed, azote appears in the expired air; and these points being established, it becomes highly probable that there is always a certain degree, both of exhalation and absorption of azote. In experiments made by Despretz and by Collard de Martigny, a pretty uniform exhalation of azote was observed.* In the respiration of fishes, it appears from the experiments of Humboldt and Provencal, that there is, more generally, a considerable absorption of azote.†

3. The proportion of carbonic acid in air that has been once breathed, has been found to vary from 3 per cent. to nearly 10 per cent.; but in ordinary respiration, probably from 3 to 6 per cent. The whole average quantity of carbonic acid given off in 24 hours, by the respiration of an ordinary sized man, has been estimated at 40,000 cubic inches, which weigh nearly 3 lb., and contain about 11 ounces of carbon. The quantity of water exhaled from the lungs in 24 hours, has been stated by Dr Thomson at 19 ounces, and by Mr Dalton at 24.‡ If these estimates be correct, as they greatly exceed the whole daily loss of weight attributed to this function (see p. 166.), they indicate a considerable and habitual amount of absorption at the lungs.

4. It appears from the experiments of Dr Prout, Dr Fyfe, and Dr Edwards, that the quantity of carbonic acid thrown off from the lungs varies considerably from various causes, that it is greatest about mid-day, least about mid-night, greater in middle age than in youth; that it is diminished by fatigue, by various weakening causes, and, at least in animals that do not hybernate, by external warmth.

* Journal de Physiologie, tom. iv. et x. † Mem. d'Arcueil, tom. ii.

‡ See Bostock's Physiology, vol. ii. p. 111.

5. Before the inquiries of Mr Ellis, and of Allen and Pepys, the most general results of experiments shewed, that the volume of carbonic acid that appears in air that has been breathed, is in general one-fifth or one-sixth less than the volume of oxygen that is found to have disappeared from it in the process.* The experiments of these last authors (chiefly confined to the human species), were thought sufficient to prove that the carbonic acid of expired air exactly equals in volume the oxygen that disappears; but the numerous and more diversified experiments of Dr Edwards, of Dulong, of Despretz and others, have again led to the belief, that in the ordinary respiration of all animals, the volume of oxygen consumed is greater than the volume of carbonic acid that appears, although the amount of the difference is very variable and often slight.†

It is known that the volume of any given quantity of carbonic acid, is just the same as that of the oxygen which it contains; and therefore, when it was generally believed, that the carbonic acid of the expired air exactly equalled in volume the oxygen that disappeared, this coincidence made it appear highly probable that the carbonic acid is formed by the union of its parts in the cells of the lungs, and that the chief office of the lungs is simply to excrete carbon, in a state admitting of its solution in the oxygen of the air. This supposition was always opposed to the fact, that exposure of the fluids to oxygen is equally essential to the life of vegetables, although it can be no object in their economy to get rid of carbon in

* Ellis, Inquiry into the Changes induced on Atmospheric Air, &c. § 122.

† Edwards, p. 410, *et seq.*, and Journal de Physiologie, t. iv. Baly's Muller, p. 309.

that way, inasmuch as carbon is actually furnished to plants by another part of the same process of respiration. And from experiments of Dutrochet,* it appears that air in its passage through the air-vessels of plants is gradually deprived of its oxygen, without acquiring carbonic acid in its place, which implies actual absorption of oxygen by the vegetable matter. And when it was ascertained, that more oxygen generally disappears in the respiration of animals, than the carbonic acid that shews itself can account for, it became more probable that the carbonic acid is exhaled, as well as the water, ready formed, and that the oxygen that disappears is absorbed into the blood.

It is no sufficient objection to this opinion that a membrane intervenes between the air and the blood at the lungs, because, in various other instances, absorption of gases certainly occurs in the living body; and besides, the reddening of blood, and evolution of carbonic acid from it, take place from the action of air on it out of the body, and through a bladder; and although it is true that part of the carbonic acid appearing in that case may come from the bladder, yet it has been proved, that the quantity of carbon that escapes in that experiment is greater than the loss of the weight of the bladder.†

The opinion, that the carbonic acid of expired air comes directly from the blood, and that the oxygen that disappears directly enters the blood, does not, however, rest merely on the ascertained inequality of volume between the oxygen that vanishes, and the carbonic acid that is evolved, but is now satisfactorily established by the following facts.

* Annales des Sciences Naturelles, t. xxv.

† C. Williams in Edinburgh Medico-Chirurgical Transactions, vol. ii.

1. Experiments by Dr C. Williams shew that oxygen and carbon, simply brought together, do not unite, so as to form carbonic acid, at a lower temperature than 400° of Fahrenheit.

2. Experiments and observations by Dr Davy* and others shew, that when mixed gases are confined over different membranes in the living body, oxygen disappears more rapidly than the others, and in greater quantity than the carbonic acid subsequently found can explain; and it was found, both by Sir H. Davy and by Muller, that a similar result follows when blood just drawn from a vein, and not allowed to come into contact with any other gas, is agitated with oxygen.†

3. In experiments by Coutanceau and Nysten‡ it appeared, that carbonic acid, in fully the usual quantity, may be exhaled from the human lungs, when the air taken into the lungs is, as nearly as possible, pure azote.

4. In many experiments by Dr Edwards, confirming more partial experiments of Spallanzani, it appeared that different animals (cold-blooded or very young warm-blooded), which can exist for various periods of time in pure hydrogen, throw off from their lungs, when confined in such an atmosphere, nearly as much carbonic acid as when breathing in atmospheric air, and more than can possibly have existed in a gaseous form, in their lungs at the commencement of the experiments.§ A similar result was obtained by Collard de Martigny, from experiments on animals confined in azote;|| and likewise by Muller, in an elaborate series of experiments, in some of

* Philosophical Transactions, 1823.

† See Baly's Muller.

‡ Coutanceau, Revision des Doctrines Physiologiques, &c.

§ De l'Influence, &c. p. 442, *et seq.*

|| Journal de Physiologie, t. x.

which he endeavoured to guard against the only obvious source of fallacy attending the observation,—viz. the possibility of gases existing in a condensed state in the cells of the lungs, even when emptied of air,—by extracting all residual air from the lungs, by the action of the air-pump, before the inspiration of hydrogen was begun.*

5. Although carbonic acid is not in general obtained in sensible quantity from venous blood, by the action of the air-pump, yet, as it was found by Hoffman, that blood artificially impregnated with carbonic acid, does not yield it to that agent, this furnishes no argument against its existence there. And the experiments of Dr Stevens first shewed, that when venous blood is agitated with hydrogen (all access to oxygen being prevented) part of the hydrogen disappears, and carbonic acid takes its place.†

6. The experiments of Magnus, in Germany, have shewn, that by passing a stream of hydrogen through blood,—which is partially absorbed in its passage, and displaces any gas previously condensed there,—both arterial and venous blood can be found to contain free oxygen and carbonic acid; but that the first is in larger quantity in the arterial, and the second in the venous blood.‡ And this is in accordance with previous experiments of Marcet and Macaire, shewing that oxygen exists in arterial blood in greater quantity than in venous;§ and also with experiments by Tiedemann, Gmelin, and Misterlich, and by Stromeyer, in which it appeared that both kinds of blood mixed with acetous acid (all access to at-

* Baly's Muller, Corrected Edition, p. 338.

† Phil. Trans. 1834. These experiments were at first too hastily set aside by Muller, but since confirmed by Bischoff, Gmelin, and Magnus in Germany.

‡ See Baly's Muller, Corrected Edition, p. 326-340.; also Maitland's Prize Thesis on the Blood, Edin. 1838.

§ Mem. de la Soc. de Physique, &c. de Geneve, vii. 5.

mospheric air being cut off) give off carbonic acid, but the venous in larger quantity.

The venous blood, and chyle, which enter the lungs by the pulmonary artery, thus appear uniformly, and in all animals, to throw off these *binary* compounds of oxygen with carbon and hydrogen. The remaining constituent of this compound fluid, azote, must of course exist in the arterial blood which leaves the lungs by the pulmonary veins in an increased proportion, and the elements are probably better adapted for entering into these *quaternary* combinations which exist in different textures. Accordingly the crassamentum of the blood, and especially the fibrin of the crassamentum, which are in greater proportion in the arterial blood, are the most animalized of the constituents of the blood, and probably the chief seat of its vital properties. Carbonic acid appears to be gradually evolved in the course of the formation of the different solids and prepared fluids; perhaps chiefly, as Dr Prout conjectures, in the conversion of the albumen of the blood into the gelatine of the animal textures.

III. In order to have a precise knowledge as to the purpose served by Respiration in the animal economy, it is necessary to attend to the successive steps of the process by which life is extinguished,—not when an animal is confined in a limited quantity of air, and therefore soon breathes an atmosphere loaded with carbonic acid, which is a poison, but when the access of air to the lungs is in any way simply prevented; *i. e.* the process of death by Asphyxia, or beginning at the lungs.

The experiments of Bichat, Brodie, and others, have satisfactorily shewn, that in such cases a quantity of the blood sent from the right side of the heart to the lungs, al-

though not arterialized there, passes on to the left side of the heart, and is propelled into the arteries; and that soon after this, the animal becomes insensible, and generally convulsed.* But the circulation of venous blood becomes gradually weaker, and, in warm-blooded animals, ceases after a very few minutes; not, however, as Bichat supposed, because the venous blood has penetrated the muscular substance of the heart, and destroyed its vital power, but, as Williams of Liverpool and Kay have shewn, because the *venous blood has failed to penetrate the substance of the lungs*, and is no longer delivered to the left side of the heart in sufficient quantity to maintain the circulation.†

Accordingly, immediately after death from this cause, the blood is found accumulated in large quantity, not in the left side of the heart and aorta, but in the lungs, right side of the heart, and great veins, indicating that the stop to the circulation had been in the lungs. And for some minutes after the circulation has ceased in a warm-blooded animal, it is still possible to restore it by blowing air into the lungs, which would not have been the case if the cause of the failure of circulation had lain at the heart.‡

Venous blood, penetrating the substance of muscles, appears, from the experiments of Dr Kay, and from some of those of Edwards,§ to support their irritability in

* Bichat, Recherches Physiologiques, Art. 7.

† See Williams's Experiments in Edinburgh Medical and Surgical Journal, vol. xix., and Kay's Experiments in the same, vol. xxix. pp. 42, 46, and his Treatise on Asphyxia.

‡ See Roesler, in Edinburgh Medical and Surgical Journal, vol. xxiii., and Goodwyn's Answer to Bichat, ditto, vol. xxxiv.

§ De l'Influence, &c. part i. chap. i., and part iv. chap. iv.

some degree, and to restore it when nearly lost, although less effectually than arterial blood.

Two questions, however, remain, not yet so absolutely decided, 1. Whether the immediate cause of the cessation of sensation and of *animal* life, preceding the failure of circulation in asphyxia, is, as stated by most authors since Bichat, the influx of venous blood on the brain? and, 2. Why does the blood fail to make its way through the lungs, when it no longer meets with oxygen there?

On the first qnestion, Dr Kay's farther experiments, in his Treatise on Asphyxia (p. 193, *et seq.*), as they shew that large quantities of venous blood may be injected (slowly and gradually) into the carotid artery of an animal without affecting its sensibility, make it at least highly probable, that the sudden failure of animal life in asphyxia is owing to the rapid diminution in the *quantity* of the blood sent to the brain and nervous system, rather than to its *quality;* and therefore, that the animal life, as well as the organic, is extinguished, not by the circulation of venous blood, but by the failure of the circulation at the lungs; and more rapidly extinguished, only inasmuch as the nervous system is a more delicate texture than others, and the changes which take place in it more immediately dependent on the continued application of the vital stimulus.

As to the second question, it has been supposed by Haller and others, that the blood stagnates in the lungs and right side of the heart, only because the mechanical actions of respiration have ceased, and the auxiliary power given to the circulation through the lungs by their alternate expansions and contractions, has been withdrawn. But in several experiments, made in Edinburgh, and reported to the British Association at Dub-

lin,* it appeared that, when an animal is confined in azote, until its breathing becomes laboured, and then, when the movements of its lungs are fuller and more forcible than natural, is killed instantaneously by concussion, the stagnation and accumulation of blood on the right side of the heart, characteristic of asphyxia, are still found.

It seems certain, therefore, that the auxiliary power to the circulation, the failure of which causes death by asphyxia, must act in the capillary vessels of the lungs, and be given by the application of the oxygen to the blood there; and as it is impossible, for reasons formerly given, to conceive that this auxiliary power can be given by an excitement of the vital power of contraction in the capillaries themselves, this fact was formerly mentioned, as an indication of powers aiding the motion of the blood, but independent of contractions of the solids containing it; and is one of the strongest illustrations of the efficacy and importance of those powers.

This account of the changes in Asphyxia, is farther confirmed by the fact, that the failure of the supply of oxygen is equally fatal to the circulation in those animals, where there are no movements of the organs of respiration, which can be supposed to act as auxiliary powers; and is even fatal to the vitality in those animals which have no distinct circulation.

It was formerly stated, that an animal in a state of activity is more speedily killed by cutting off its supply of oxygen, than one in a state of torpor; and, accordingly, it is known that the living human body, in the state of syncope, can bear the privation of air (as by submersion in water) considerably longer than when in perfect health.

* Fifth Report of British Association, Trans. of Sections, p. 90.

The reason of this has been supposed to be, that the privation of air, when the circulation is vigorous, implies a fuller penetration of all the textures by venous blood, than the same privation of air when the circulation is languid. But according to what has now been explained, the difference must depend on the more sudden and greater diminution of the quantity of the blood penetrating the different textures, rather than its venous quality; and upon the law formerly stated, that a vigorous state of vitality requires a rapid and full supply of blood, whereas a languid vitality requires a less supply or less stimulating blood.

The whole doctrine of the fatal changes in Asphyxia, is confirmed in the most satisfactory manner by the peculiarities of structure, already described, as existing in warm-blooded diving animals, chiefly the Cetacea, whereby they are enabled to bear the occasional long continued privation of air without injury to their viscera from the consequent stagnation of blood; and without suspension of the flow of arterial blood through the nervous system, and other textures; notwithstanding that they are not provided, as the reptiles are, with any apparatus which can serve as a reservoir of air during their submersion.

The experiments of Cruickshanks,* Bichat, Brodie, and others, shew that in what is properly called death by Coma, or beginning at the Brain, where the primary change is gradually increasing insensibility, the circulation survives the respiration, and comes to a stand in the same way as now described, and apparently from the same cause, viz. the imperfect vitality of venous blood. This is indeed sufficiently proved by the effect of artificial respiration,—often practised on animals since the time of Fontana,—in maintaining the circulation, long after it would other-

* Philosophical Transactions, 1795.

wise have ceased, when the functions of the brain have been suspended, or when the head has been cut off. But the blood becomes venous in the case of death by coma, not because the air cannot enter the lungs, but because the sensation which prompts to the act of respiration is extinguished, and the lungs are not expanded to receive it. In the one case, the sensibility fails because the blood has become venous; in the other, the blood becomes venous because the sensibility has failed. The Organic Life is extinguished in the same way in both cases, viz. by the defective circulation of venous blood; but the extinction of Animal Life is, in the one case the consequence, and in the other the cause, of the failure of Respiration.*

In the case of approaching death by coma, from an injurious influence acting primarily on the nervous system, the blood may therefore be arterialized, and kept in motion for a time, by artificial respiration, after the natural respiration has ceased; and, if the cause which has extinguished sensibility has been only temporary, the organic life may in this way be maintained, until the effect of that cause on the nervous system, and on the animal life, has gone off, and the natural mode of breathing been resumed;—as has been shewn by the recovery, thus effected, of animals under the influence of narcotic poisons, by Sir B. Brodie,† and in one case of apparent death by opium, in the human body, by Mr Whately.‡

The Asphyxia, which is in general gradually produced by section of the 8th pair of nerves in the neck (independently of the effect of that operation in causing coma of the glottis) has been the subject of much discussion, and has been considered by some as indicating that

* See Bichat, Recherches, &c. Art. 10.

† Philosophical Transactions, 1812.

‡ London Medical Observations and Inquiries, vol. vi.

some influence constantly derived from the nerves is essential to the arterialization of the blood. But Brachet found that when the stagnation of blood in the lungs, consequent on this operation, is beginning, the circulation, and the florid colour of the blood, may be restored by the artificial respiration.* And the recent and elaborate investigations of Dr J. Reid seem to have established two points as to the result of this experiment; 1. That it is not uniform,—some animals thus treated gradually recovering the natural mode of breathing, after being affected by the operation, and having no subsequent lesion of their lungs;† and 2, That the lesion which usually takes place in consequence of the operation, viz. congestion and extravasation of blood and consequent partial condensation, chiefly of the depending portions of the lungs, with serous and frothy bronchial effusion, may be explained simply (as Sir B. Brodie long ago conjectured) by the diminished sensibility of the lungs, and diminished frequency of respiration; being just the same as take place in the human body, although the par vagum be sound, and the lungs not primarily disordered, if, by any cause acting in the brain or medulla oblongata, the respirations are permanently reduced (as after that operation) to less than ten in the minute.‡

It appears from the experiments of Mr Broughton,§ that when pure oxygen is breathed so long that the blood is arterial even in the veins, the nervous system is affected as by a narcotic poison, and death takes place by coma

* See Recherches Experimentales, &c. sect. ii.

† This is confirmed by an observation of Magendie (see Leçons sur les Phenomenes Physiques de la vie, t. i. p. 203), also by Leuret and Lassaigne, and some previous authors.

‡ Edinburgh Medical and Surgical Journal, 1839.

§ Quarterly Journal of Science, April 1830.

in the way above described ; so that the effect of an excess of oxygen absorbed into the blood, upon the brain, is very similar tó that of carbonic acid ; and a certain dilution of oxygen by azote is necessary to qualify it for producing that change on the blood, which enables it to maintain the vital action of the nervous system. A standard degree of purity is therefore as necessary a condition to vitality, as a standard temperature of the atmosphere.

CHAPTER XI.

OF ANIMAL HEAT.

It is evident that one of the changes continually in operation, in living animals, is an evolution or disengagement of caloric, whereby their temperature is generally kept above that of the surrounding media, and the effect of which is much aided, in many animals, by the nature of their coverings, and by the thickness of the adipose texture beneath them.

As the formation of carbonic acid, by union of its constituents, is a process which is attended with evolution of heat in all other circumstances where it occurs, and as the ordinary temperature of different classes of animals appears generally proportioned to the amount of oxygen which they consume, and of carbonic acid which they exhale,* it has generally been supposed, since the time of Dr Black, that the union of carbon and oxygen to form the carbonic acid of the expired air, is at least a great source of the heat of animals.

This is strongly supported by the fact, that animals in a state of winter torpor, or in a state resembling that, when their respiration and circulation are slow and feeble, and their temperature very low, may be roused by excit-

* Although some exceptions may be stated to this law, it is strikingly confirmed by various individual observations, *e. g.* by those of Dr Davy on the structure of the gills, and on the temperature of certain fishes, of unusually warm-blood; and by those of Mr Newport on the temperature of different insects. Phil. Trans. 1834 and 1835.

ing sensations,—even by the sudden application of intense cold,—and in proportion as their respiration becomes more frequent and fuller, and their circulation stronger, their temperature rises, often by many degrees, while that of the surrounding air is unchanged or even lowered.*

Farther, some of the observations made on the temperature of animals, in which the circulation has been maintained, after apparent death, by artificial respiration, seem to leave no room for doubt as to the influence of this cause on animal heat; because they shew that when the insufflation of cold air into the lungs is not too frequently repeated, and is successful in maintaining the circulation, it may materially retard, instead of accelerating, the cooling of the animal.†

There is an obvious difficulty in understanding how a cause which appears limited to one organ, should produce the elevation of temperature which is general over the body. For, although it appears from the observations of Dr Davy and others, that the temperature of arterial blood in the chest, is about 1° higher than that of venous; and that the temperature of the chest is generally several degrees higher than that of the extremities; yet this difference is certainly not so great as would be found, if the only calorific change were at the lungs, and the rest of body were only warmed by the superior temperature of the arterial blood flowing thence.

Dr Crawford, supposing the whole calorific change to be at the lungs, endeavoured to surmount this difficulty

* See Edwards, De l'Influence, &c. Part iv. Chap. 10.

† See particularly Experiments by Dr Hastings, in Dr Wilson Philip's Experimental Inquiry, p. 223; by Dr Hales, in London Medical and Surgical Journal, 1814; and by Dr C. Williams, in Edinburgh Medico-Chirurgical Trans. vol. ii.

by shewing, that arterial blood has a greater specific caloric than venous, from which it follows, that the blood which becomes arterial at the lungs will necessarily absorb the greater part of the caloric evolved by the change on the air there, and only set free this caloric in the capillaries of the system, where it becomes venous again. And although Dr Davy's estimate of the difference of specific caloric in arterial and venous blood, is much less than Dr Crawford's, yet even he has assigned a higher specific caloric to arterial blood; and no great reliance can be placed on any estimate of the exact difference.

But as it appears now sufficiently ascertained, that the carbonic acid which is exhaled at the lungs is not formed there, but generally throughout the body, it is obvious that the calorific change, now in question, is not confined to the lungs, and therefore, that the difficulty which Dr Crawfurd attempted to obviate does not exist.

There appears, then, sufficient grounds for believing, that the formation of the carbonic acid which is exhaled at the lungs, is one essential element in the process by which the heat of animals is maintained; but it is very doubtful whether this is a sufficient cause for the whole caloric which is evolved in their bodies. The experiments of Dulong and of Despretz, made by enclosing a small animal in a box placed in water, measuring and analyzing the air which it inspired and that which it expired, observing the elevation of the temperature of the water which corresponded to the evolution of a given quantity of carbonic acid from its lungs, and comparing this with the estimate, obtained in a nearly similar way by Lavoisier, of the quantity of caloric evolved by the combustion of a given quantity of carbon,—lead to this result, that the quantity of carbonic acid thrown off in a given time from an animal, is sufficient to account for

about three-fourths of the caloric which the animal evolves (from 50 to 90 per cent.), but not for the whole of that caloric;* and this is confirmed by farther experiments by Muller and others.

It is highly probable, that *several* of the chemical changes which are wrought on the blood during the greater circulation, are attended with an evolution of caloric;† and that the application of oxygen to the blood, in respiration, is essential to the animal heat, not simply by combining with carbon, and so generating heat, but by adapting the blood for the maintenance of the *various processes* (partly chemical and partly vital), by which it is to be changed in the living body; and of which one of the results is, the formation of the carbonic acid which appears in the expired air.

The temperature of the body is not raised by voluntarily increasing or quickening the act of respiration; but it is raised by voluntary exertions of other muscles, which accelerate the circulation, and so necessitate an increased frequency of respiration; and this appears to indicate, that it is dependent, not simply on the application of oxygen to the blood, but on various changes, chemical and vital, which take place during circulation, and to the maintenance of which, the oxygenation of the blood is one essential condition.

The evolution of heat in the animal body has been found, in the experiments of Sir B. Brodie and others, as well as in the numerous causes of disease in the human body, recorded by Mr Earle and others, to be much influenced by injuries of the nervous system, being generally diminished in those animals, or in those parts of the human body, in which the chief functions of the nervous

* Journal de Physiologie, t. iii. and iv.

† See C. Williams, Edin. Medico-Chirurg. Trans. vol. ii.

system have been lowered or suspended; and in a few cases, being increased in consequence of such injuries. But as we know that the circulation, especially in the capillaries, and that secretion and nutrition, are easily and variously affected by injuries of the nervous system, we can readily understand this farther influence of such injuries; without being obliged to suppose that any influence derived from the brain or nerves is essential to animal heat, or that chemical principles are inadequate to explain it. Accordingly, in numerous experiments by Chossat, it appeared, as a general result, that the injuries of the nervous system, which lower the temperature of animals, are the same which manifestly diminish the process of secretion and nutrition.*

In Sir B. Brodie's experiments, after the head of an animal was cut off, and the circulation maintained by artificial respiration, repeated at least as frequently as the natural breathing of the animal, the cooling of the animal was accelerated, although the usual quantity of carbonic acid was thrown off for some time. But, according to our present belief as to the source of the carbonic acid of expired air, what was thus thrown off must have been formed previously, and the changes leading to the formation of fresh carbonic acid appeared, in the latter part of the experiments, to have been greatly diminished by the injury.

It is necessary to distinguish carefully between the power of generating heat in the animal body, and the power of bearing cold. The former appears to be a chemical effect of the changes which take place on the blood in the living body, and is, in general, directly proportioned to the vigour with which the Circulation and Re-

* Memoire sur l'Influence du Systeme Nerveux sur la Chaleur Animale.

spiration, or the analogous functions in lower animals, are performed. It is greatest and most enduring at the age of greatest strength, and during winter, in those animals which preserve their strength and activity in that season, —the velocity of their circulation, and their consumption of air being at the same time augmented. The latter appears to be an original endowment of the living matter, varying in different kinds of animals, and in different states of the same; and is greatest in cold-blooded animals,—in animals that hybernate during their state of torpor,—and in the young of warm-blooded animals; *i. e.* in cases where the circulation is languid, or easily depressed; it varies therefore nearly in the inverse ratio of the power of generating heat.*

Animals possess the power of maintaining their own temperature, not only when that of the surrounding air is lower, but also when it is higher than themselves; and in the experiments of Sir C. Blagden, De la Roche, and others, a temperature approaching to, or even exceeding, that of boiling water, has been borne by the human body, for many minutes, without more elevation of the temperature of the skin than 4° of Fahrenheit. The experiments of De la Roche and Berger† have shewn that a lower temperature than that of the air is in like manner maintained by moist and very porous substances, although not endowed with life; and again, that when hot air is saturated with humidity, so as to allow of no evaporation, the temperature of animals confined in it is raised, and they are soon killed. This power of resisting the influence of high temperatures seems therefore to be owing entirely to the increase of evaporation from the surface, and the cooling effect of that process.

* See Edwards, De l'Influence, &c. part i. chap. ii.; part iii. chap. i. ii. iii. iv.; and part iv. chap. vii.

† Journal de Physique, tom. lxii. lxxi. lxxvii.

CHAPTER XII.

OF DIGESTION.

The processes of Nutrition and Excretion, already considered, manifestly require, in the human body, as in all living beings, that the nourishing fluid shall not only be regularly purified by exposure to air, but also receive frequent supplies both of solid and fluid materials, to compensate for the continual losses which it undergoes; and the conditions formerly stated as essential to the vital agency of the nourishing fluid in all animals, require that much of the matters taken into the system for this purpose shall have been previously organized; and that it shall be acted on by part of the fluids of the body into which it is taken, and so far assimilated by their agency, before it is applied to its destined purpose.

All these objects are accomplished in vegetables, and perhaps in the lowest order of animals, without the appropriation of any particular organs to the reception of unassimilated nourishment, and without the aid of any appetites or other mental acts. The circumstance, in the life of animals, which appears especially to require a separate apparatus for the occasional reception and gradual assimilation of food, is their faculty of Locomotion, which precludes the possibility of their continual adaptation to the reception of solids and fluids from without, and makes it necessary that they should carry about with them, and gradually avail themselves of, the materials by which they are to be nourished. This condition in the economy of animals, therefore, imposes the necessity of the

function of Digestion, as subsidiary to that of Nutrition.*

In all animals, the first part of the vital actions by which these objects are accomplished, is put under the guidance of Sensations; but as the solids and fluids, which are the subjects of digestion, are not always within the reach of animals, the muscular actions, by which these sensations are to be appeased, are not made directly consequent on their being felt (as is the case with the movements of respiration), but are linked with the sensations by the more complex mental processes to which we give the names of Appetites and Instinctive propensities. It is probably for a similar reason, that the chemical part of the function is provided for, not by a solvent fluid continually formed in the stomach, nor even by one which is formed there simply from the irritation of the aliment, but by one which is thrown out under the influence of nerves, and probably of sensations connected with those nerves, as appears from the usual effects of section of the par vagum, formerly stated. And as it is dependent on these different mental acts, so this function differs from all those which we have yet particularly considered, in this important circumstance, that wherever it exists it is fitted and intended to be a *source of enjoyment.*

As the materials on which this function is to be performed are numerous and diversified, and the circumstances of the animals that perform it very different, so we observe great varieties, both in the mental and physical part of the process, in the different orders of animals; tracing it in the ascending series of living beings, from the polypi, in which it is seen in its simplest and perhaps most characteristic form, consisting merely in the solution

* See Cuvier, Leçon 16.

and immediate appropriation of part of the ingesta, and the immediate rejection of others,—and performed by any of the surfaces of the living animals,—up to the complex processes in the mammalia. Without altering the general plan of the function, or even the essential parts of the organs concerned in it, Nature makes such additional provisions, in the instincts by which the reception of food is guided, and in the organs by which it is assimilated, as are suited to the circumstances in which each animal is placed, to the food on which it is to subsist, and to the ulterior purposes which it is to serve in the world.

For example, the agility, ferocity, and predatory instincts, and the canine teeth, high zygomatic arches, and strong temporal muscles of the carnivorous quadrupeds, with their short and simple alimentary canals. fit them for subsisting on prey which it is difficult to procure and to prepare for introduction into the stomach, but which requires no great chemical change to be wrought on it there, that it may be assimilated to the animal textures; while the quiet habits, the comparatively feeble limbs, and large bodies, the ruminating instinct, the deficiency of canine and incisor teeth, the complex stomachs, and long intestines of the ruminating animals, fit them for obtaining the greatest quantity of nourishment from vegetable matters, which they can easily procure, and easily reduce to the proper consistence for entering the stomach and bowels; but which must necessarily undergo much change there, before they can be applied to the nutrition of animals. Again, the camel and lama, which traverse the deserts, are instinctively led to swallow large quantities of water beyond what the purposes of their digestion and nutrition immediately require; and their first and second stomachs are provided with numerous cells, with muscular orifices, in which it is securely stored, until it is

required to assuage thirst, or to assist the assimilation of food. And graminivorous birds, instead of having heavy jaws and teeth, for the requisite comminution of their food, are prompted by instinct to swallow gravel, and furnished with stomachs of extraordinary muscular strength, the action of which, aided by the attrition of the gravel, is effectual for the purpose.

The mental powers and inclinations, which lead the whole human race to practise the art of cookery, are equally a part of the plan of Nature, for the management of this function in our species, as any of the instincts of animals; and enable us to dispense with additional provisions, in the structure of the digestive organs, which would otherwise be necessary to secure the digestion of many articles of our diet.

The different actions, however, which immediately precede the reception of food and drink into the stomach, even in our species, are truly *instinctive*; that is, they are excited by mental determinations, which are linked to certain complex sensations,—to a combination of the simple feelings of hunger and thirst, with those which result from the sensible qualities, especially the taste and smell, of the objects by which hunger and thirst are to be allayed; and although very complex, they require no experience or education.

Hunger and Thirst, in the natural state, are sensations probably dependent on the nerves of the stomach almost exclusively; for although thirst is naturally referred to the mouth and fauces, it has been found, in cases where a preternatural opening has been made into the œsophagus from the neck, not to be relieved by any applications to the upper portion of the divided œsophagus, although quickly relieved in the usual way by drink taken into the stomach. They are not destroyed, but manifestly per-

verted, by section of the eighth pair of nerves. Thirst would seem to depend simply on want of the usual moisture on the mucous membrane, and is relieved by whatever is effectual in restoring the natural condition as to moisture. Hunger is certainly not dependent on the action of the solvent liquor of the stomach, already effused on the mucous membrane, because it is instantly destroyed by mental emotions, which cannot remove such a liquor ; and besides, we shall see reason to think, that the solvent liquor does not usually exist in the stomach, at the time when hunger is most felt. It is probably connected with a particular state of the contraction of the muscular fibres of the stomach ; but, according to the observations of Magendie, at the time when it is most felt, the stomach is not strongly contracted on itself.

Whatever be the conditions under which the nerves of the stomach become the seat of these sensations, it is certain that, in the healthy state, they are a true index, not only to the state of the stomach, but to the immediate wants of the system at large.

The sensations excited by the smell, taste, or touch in the mouth, of alimentary substances, are naturally either agreeable or disagreeable, especially when hunger or thirst co-exist with them ; but these feelings are susceptible of much alteration by custom and habit. These complex sensations, and accompanying mental emotions, produce two effects,—an increased flow of the secretions of the mouth and salivary glands,—and certain definite instinctive muscular contractions ; and the different varieties of these sensations prompt to corresponding variations of the muscular actions that succeed them. It is because they give occasion to these instinctive muscular actions, that these sensations are called Appetites. These actions, however, are always distinguished from those which de-

pend on sensation simply, by this circumstance, that they are felt in ourselves, and inferred from observation in other animals, to be completely under the control of the will, even when the sensations, which prompt to them, are felt the most keenly. There is a propensity leading directly to the performance of a certain definite action, on each of these complex sensations being felt; but the particular mental act, called a Volition, always intervenes between the sensation felt, and the muscular action excited.

In this way, the contact of liquids with the lips excites, and the reception of liquids into the mouth is much promoted by, the instinctive but complex act of Suction, in which, by partially closing the lips, and either moving the tongue backwards and forwards after the manner of a piston, or by acts of inspiration, or by these two movements together,—we cause the pressure of the atmosphere to urge fluids into the mouth.

The contact, especially of solid food, with the interior of the mouth, excites also the act of Mastication, performed by alternating contractions of the muscles, which pull the lower jaw upwards towards the bones of the head and face, and downwards towards the os hyoides and sternum,—the jaw moving on its condyles as a lever of the third order, and subjecting the food to the pressure of the teeth.

The increased flow of the saliva and mucus by the mouth is unconnected with any act of instinct or volition, which never affects any secreting organs; but results directly from the complex mental feeling above described, and may be reproduced by the emotion, which forms a part of that feeling, even when that is excited by recollection, independently of any physical impression on the parts.

The experiments of Sir Charles Bell and Mr Mayo are quite satisfactory as to the dependence of the sensations of the lips and mouth on the ganglionic portion of the fifth nerve;—as to the dependence of the contractions of the temporal, masseter and pterygoid muscles, which elevate and close the lower jaw, on the anterior portion of the fifth, which does not pass through the Gasserian ganglion,—and as to the dependence of the motion of the lips and tongue on the portio dura and ninth nerve. The particular nerves concerned in the depression of the lower jaw by the digastric, genio-hyoid, and mylo-hyoid muscles, &c. have not been so clearly demonstrated.

We can have no doubt, that the increased flow of the saliva and mucus, consequent on the sensations and emotions described, is effected through the nerves of the salivary glands and mucous glands and membrane; and these are chiefly the ganglionic portion of the fifth, and branches of the eighth pair and sympathetics; but the influence of these nerves on the secretions has not been distinctly elucidated by experiment.

The food, comminuted and moistened in the mouth by the means now mentioned, is prepared for the act of Deglutition, the first and most complicated part of which is also guided by an instinctive impulse. The food is first pushed back by the tongue, till it arrives within the sphere of action of the constrictor muscles of the pharynx; but at the same time that it is moved downwards by the successive contractions of their fibres, several other movements take place. 1. The passage of the fauces is narrowed by the contraction of the Constrictores Isthmi Faucium, in the anterior arches of the palate. 2. The Velum Pendulum Palati is raised and stretched by the Levator and Circumflexus Palati, and the posterior arches of the palate are approximated by the contraction of that pha-

rynx and by the Palato-pharyngei muscles, and thus the food is directed past the opening of the posterior nares. 3. The glottis is closed, partly by depression of the epiglottis, but chiefly by apposition of the arytenoid cartilages. 4. The larynx, and lower portions of the pharynx, attached to it, are drawn *upwards*, partly by the muscles connecting the larynx to the os hyoides and lower jaw, but more especially by the lowest of the constrictors, and by the Stylo-pharyngeus and Palato-pharyngeus; the moveable origin of the latter muscle in the velum pendulum being fixed at the time. By this combination of movements, the food or drink is rapidly and safely carried past the openings to the nares and lungs, and lodged on the lower part of the pharynx, after which its descent is slow.

Great part of this movement is distinctly voluntary, though prompted by instinct only; but the actions of the constrictor muscles of the pharynx in it appear to be strictly dependent on the sensation caused by the matter to be swallowed, when it touches the mucous membrane of the pharynx, because they cannot be correctly imitated by any voluntary effort, when there is no substance to be swallowed. The experiments of Dr Reid have shewn that the glosso-pharyngeus nerve is merely a sensitive one, and is useful in this action by transmitting upwards to the medulla oblongata the impression made on the mucous membrane of the mouth and fauces, which immediately acts downwards on the muscles concerned, partly by the ninth nerve, which is strictly voluntary, and partly by the pharyngeal branch of the par vagum, which, although a motor nerve, seems to be only partially, if at all, under the dominion of the will. The muscles of the tongue are moved by the first of these, those of the soft palate and pharynx chiefly, perhaps not exclusively, by the last.*

* See Edin. Med. and Surg. Jour. No. 134.

In passing from the Pharynx to the Œsophagus, the food comes within the field of Organic Life, and its subsequent movements are neither excited by the will, nor attended by the consciousness of the individual. The essential parts of the whole canal through which it now passes, are the mucous membrane on which it moves, and the muscular coat, provided both with longitudinal and circular fibres, by which it is propelled, but which is much thicker and stronger in the œsophagus than in the stomach or intestines; and to these, in the abdomen, the serous coat is added.

The muscular action propelling the food is of the same general description in all parts of the canal,—each portion of the canal contracting as the food distends it, and continuing contracted until the portion next in advance has contracted also; but the rapidity of the motion is very various in different parts and at different times. The lower part of the œsophagus exhibits, when exposed, continued gentle movements of contraction and relaxation; and the whole movement of the œsophagus appear, from Dr Reid's experiments, to be dependent on the eighth pair of nerves, which form a plexus about the part, and nearly to cease on the division of these nerves;* on which account, after that operation, the food taken distends the whole œsophagus and pharynx. In a slighter degree, a similar movement in the stomach appears also to be determined by these nerves.† But the stomach is certainly much less under their influence than the œsophagus, and no effect results from division of any nerves on the peristaltic movements of the intestines.

When the stomach receives the food, its great left sac

* Magendie, Precis, &c. Reid, *loco citato*, p. 42. *et seq.*

† Breschet and Edwards in Arch. de Med. 1825, and Tiedemann and Gmelin, Recherches sur la Digestion, sect. iii. p. 374.

is chiefly distended, its surfaces rounded, and its great arch thrown forward; and in this position it retains the food for a time, which is very various in different cases, letting successive portions escape by the pylorus, after they have undergone certain changes; which do not begin immediately after it is taken, and are not completed until several hours after an ordinary meal. The chief obstacle to the passage of undigested materials from the stomach, is the contraction of the circular fibres at the pylorus; and for this we can assign no cause but a peculiarity of the irritability of these fibres.

The sensations which prompted the reception of food and drink abate after they are received into the stomach, but not simply in consequence of its distention; probably rather in consequence of the increase and alteration of the secretion of the stomach thereby effected. They are more easily appeased by a small quantity of nutritious food, or of slightly stimulating drink, than by larger quantities of other matters. Different and more grateful sensations succeed them, which are certainly chiefly dependent on the eighth pair of nerves; because, when these are cut in the neck, the animal is not aware of the condition of his stomach, and continues to eat after that is distended with undigested food. The sensations which accompany and succeed the reception of food into the stomach, prompt to no muscular action, but are probably of importance in exciting the secretion of the stomach.

The materials on which the function of Digestion, in the human stomach, may be performed, are the chief proximate principles of animal and vegetable substances, —Fibrin, Albumen, Gelatin, Osmazome, &c., the vegetable Gluten, Starch, Gum, Extractive matter, Sugar, and animal or vegetable Oil. In regard to these the following facts demand attention.

1. They answer for the purpose of Digestion best, when in a medium state of aggregation and density; hardened or dried food, solid albumen in any form, vegetables not softened by boiling, are acted on with difficulty in the stomach; and, on the other hand, very soft or liquid aliments seem to give but little stimulus to the digestive process. Of the different proximate principles, Oil is perhaps, in any form in which it can be taken, the most difficult of digestion.

2. It has been fully ascertained by Magendie, Leuret and Lassaigne, and others, that a certain *variety* of articles, whether of vegetable or animal food, is necessary in various animals, on which experiments were made, in order that the due action of the stomach on them may take place, and that they may be effectual for the nourishment of the body; the animals that were fed on single chemical principles only becoming almost uniformly, after a time, unable to digest sufficient quantities of these for the support of life. The importance of the art of Cookery to the human species, no doubt, consists in its fulfilling these necessary conditions as to the consistence and the mixture of aliments.

3. According to Dr Prout, all the articles of food which are used by the human species may be arranged, according to their chemical relations, under three heads, the Saccharine, the Albuminous, and the Oily; the first of which consists of carbon in different proportions (from 30 to 50 per cent.) chemically combined with water; the two last of compound bases also united with water; the carbon in some of the oils is nearly 80 per cent., and its proportion therefore varies, in the different aliments, from 30 to 80 per cent. The prototypes of these three classes of aliment exist in the milk; and of these three he thinks that a mixture of two at least must be taken, either to-

gether or soon after one another, to answer the purposes of Digestion and Nutrition.

4. There is much variety in individuals as to the kind of food that is found easy or difficult of digestion; and by repetition and habit, those kinds which are at first unsuitable, are very often found ultimately to become easy of digestion and nutritious. This is perhaps sufficiently explained by the connexion of the process with the sensations of the stomach, and by the general principle of the influence of habit on sensation.

When such food as is suitable for digestion has been received into the stomach of a warm-blooded animal, and is retained there in the usual way, the mucous membrane becomes more vascular than before, its villi prominent, and its cryptæ or minute cells appear full of their secreted fluid; and this increased flow of the secretion of the stomach is manifestly promoted in the first instance by rest.

When the stomach is examined two or three hours after food has been freely taken, the portion of the alimentary mass which lies outermost, or next the mucous membrane, is found most altered, and the central part least altered; but towards the pylorus the alteration of the whole contents is more uniform; apparently because the portions of food that have been acted on by the fluid at the surface of the mucous membrane, all round the stomach, pass gradually on to the pylorus, while fresh portions from the interior of the mass take their place on its exterior; and after being subjected to the same change, are pushed forwards in their turn.*

The change that is wrought on the food during this process is its conversion, more or less complete, into the homogeneous, greyish, pultaceous matter called Chyme.

* Wilson Philip, Experimental Inquiry, ch. vii. sect. i.

It is satisfactorily ascertained by numerous experiments of Montegre, Prout, Magendie, Tiedemann and Gmelin, Leuret and Lassaigne, and others, made on a variety of animals, using very different kinds of food, that this chyme, in the healthy state, is uniformly, though slightly, *acid*.

Farther, the following facts leave no room for doubt, that the acidity, found in the healthy state, does not depend on fermentation of the alimentary matters; but on the nature of the secretion of the stomach itself.

1. The chyme is acid from the commencement of its formation, *i. e.* long before the same substances, kept at the same temperature, can have run into acetous fermentation.

2. The secretions of the living stomach, so far from promoting, at least the putrefactive fermentation, are decidedly antiseptic.

3. The acid found in the chyme is, for the most part indeed, the lactic, *i. e.* a modification of the acetous; but in part also it is the muriatic, which of course cannot be generated by fermentation.*

4. The presence of the same acids in the stomach is determined, not only by the reception of food, but by the excitation given by grains of pepper, or even by particles of sand.†

In fasting animals, it appears that this acid liquor is seldom found in the stomach, but its formation appears always to be excited, in the healthy state, by the presence of food in the stomach; and even its quantity to be greater, in proportion as that food is more difficult of

* Prout, Philosophical Transactions, 1824, and Annals of Philosophy, vol. xii.; Tiedemann and Gmelin, Recherches sur la Digestion.

† Tiedemann and Gmelin, Recherches, &c. sect. ii. p. 161.

digestion, if within the limits of the natural food of the animal.*

The observations of Dr Sprott Boyd have made it probable that there is a peculiar structure, consisting essentially of short tubes, set at right angles to the surface of the mucous membrane of the stomach in all the higher animals, designed for the secretion of the true gastric juice.†

This enables us to understand, that the fluid taken from the stomach of fasting animals should often have been found, as in the experiments of Montegre, ineffectual in producing an *artificial digestion*, i. e. solution of the food, and formation of chyme, when mixed with alimentary matters at the temperature of the body; and yet that in many experiments of Reaumur, Spallanzani, Stevens, Leuret and Lassaigne, &c., alimentary matters introduced into the stomach in perforated balls or tubes, should have undergone digestion, evidently from the action of a fluid in the stomach; and that in those of Tiedemann and Gmelin, the acid chyme itself, beginning to form in the stomachs of animals recently fed, should have been found effectual for the artificial digestion, out of the body, of fresh aliments.‡

The solvent power of the acid liquor formed in the stomach after the reception of food, is most clearly demonstrated by its having dissolved portions of the stomach itself after death, in various cases, both in the human species and in animals, where death has taken place suddenly during the act of digestion. But it is seldom, and perhaps never without disease of the secretion at the stomach, that any such solvent power is found to have

* Tiedemann and Gmelin, Recherches, &c. sect. iii. p. 335.

† Recherches, &c. sect. iii. Exp. 30 and 31.

‡ Inaugural Essay, Edin. 1386.

been exerted where death has taken place during fasting.*

The observations of Dr Beaumont, made in a case where perforation of the stomach, from a wound, which had healed, allowed its interior to be inspected, fully confirm the statements now made, as to the erection of the villi, after food has been taken,—as to the flow from them of an acid liquor at that time,—and as to the effect of this acid liquor in dissolving aliments at the temperature of 100° out of the body, although more slowly than in the stomach itself; and shew farther, that the flow of this liquor is diminished, and digestion in consequence retarded, whenever the nervous system is strongly affected, whether by physical or mental causes.†

But a farther important addition to our knowledge on this subject, was made by Eberle, Schwann, and Muller, who have shewn, that an infusion of the mucous membrane of the stomach is more powerful, as a solvent of aliments, than any other liquid containing the same acids, in the same proportion ; and that the same solvent power exists in an infusion of that membrane, made after it has been deprived of its acid by repeated washing, then dried, digested in water, and again acidulated with muriatic or acetous acid. Hence it appears, that a peculiar animal principle, soluble in water, and in those very dilute acids, exists in the mucous membrane of the stomach, and there only, so far as is known, and is an important auxiliary in

* See Carswell on the Digestion of the Coats of the Stomach after death, in Edinburgh Medical and Surgical Journal, October 1830; and Gairdner on Perforation of the Stomach, in Edinburgh Medico-Chirurgical Trans. vol. i.

† Experiments and Observations on the Gastric Juice, and the Physiology of Digestion.

digestion, especially of fibrin and albumen ; and to it the name of Pepsin has been given.*

Some part of the aliment always passes the pylorus along with the chyme, unchanged ; and according to the observations of Londe,† made on the human body, in cases of artificial anus, animal food is longest retained and most altered in the stomach, and vegetable food passes out of the stomach more rapidly, and less changed, and probably undergoes more change in the intestines.

The chyme in the stomach appears to contain little or no matter having exactly the chemical properties of albumen (unless albumen has formed part of the food taken), and therefore shews little approximation to the chemical nature of the blood.‡ But, according to the microscopical observations of Leuret and Lassaigne, it would seem to contain a number of globules, resembling those of the blood, although of smaller diameter, and having the same tendency to arrange themselves into fibres. And in the stomachs and intestines of the cold-blooded animals, these and other authors have described a number of globular bodies, which seem to have a power of spontaneous motion, resembling animalcules.§

The passage of the chyme out of the stomach does not take place uninterruptedly, but by successive series of peristaltic movements along the stomach and duodenum, each of which is preceded by a series of slighter movements in the opposite direction.||

* See Baly's Muller, p. 543, *et seq.*

† Archives de Medecine, tom. x.

‡ See Prout, in Annals of Philosophy, 1819, and Tiedemann and Gmelin, Recherches, &c. sect. iii. p. 344 and 388.

§ Recherches pour servir à l'Histoire de la Digestion.

|| Magendie, Precis, &c.

After passing the pylorus, and mixing with the Bile and Pancreatic Juice, which slowly distil into the duodenum, and with the Mucus of the Intestines, the Chyme and undissolved aliments gradually separate into the Chyle, which is absorbed into the lacteals and the Feculent matter, which passes on to the large intestines; and the more watery portion of the chyme seems to be absorbed away from the rest chiefly by the veins, both of the stomach and intestines.

The peculiar matter of the Bile appears manifestly to connect itself with such substances as have passed unchanged from the stomach, and to become part of the feces;* and is no doubt useful, by stimulating both the mucous secretion and the peristaltic movements of the intestines. The free alkali of the bile and perhaps of the mucus unites with the acids of the chyme, and also with any oil which the chyme may contain; and it is probably in part from this cause that the acidity of the contents of the canal gradually disappears in the small intestines.† The white colour often seen in part of the contents of the intestines, as well as in the lacteals, appears to rise chiefly from oily articles of food uniting themselves with the alkali.‡

It appears, on comparing the experiments of Mr Brodie, Mr Mayo, Magendie, Leuret and Lassaigne, and Tiedemann and Gmelin, that after the biliary ducts are tied in animals, a matter, possessing the chief properties, though not the usual white colour, of chyle, may be formed, and digestion go on to a certain degree; but cases of jaundice, without organic disease, in the human body, seem sufficiently to indicate, that digestion in these circumstances is imperfect.

* See p. 152. † Prout, Tiedemann, and Gmelin.

‡ Tiedemann and Gmelin, Magendie.

As the Pancreatic Juice contains much albumen, and as it is found most abundantly in herbivorous animals, which have no albumen in their food, it is thought probable that a greater portion of it, than of the bile, goes to the formation of the chyle. It is certain, from the experiments of Dr Prout, that albumen is found in larger proportion, and more distinctly formed, in the fluid of the small intestines, during digestion, than in the stomach; that it is found still more distinctly, and in larger proportion, in the lacteals and thoracic duct; and that it is not found at all in the larger intestines. The organic globules described by Leuret and Lassaigne, and which are probably composed chiefly of albumen, or animal matter closely resembling it, are also seen much more abundantly in the contents of the small intestines than of the stomach.

The chyle has been observed to have an alkaline reaction, not only after it has passed through the mesenteric glands, as stated by Tiedemann and Gmelin, but immediately after it has been absorbed from the acid chyme of the intestines.*

The chyle, which is found in the lacteal vessels, certainly contains very numerous globules, similar to those in the blood, but smaller and of a white or grey colour; and the formation of these globules is probably the main object of the whole process of digestion. After passing through the mesenteric glands, and in the thoracic duct, *i. e.* when it must have been mixed with the contents of lymphatic vessels, and probably with some of the contents of arteries,† the albuminous contents of the chyle are more distinct; it contains a little fibrin, and coagulates on exposure to air, after the manner of blood, although

* Curtis Thesis on the Functions of the Cœcum, Edin. 1837 (not published).

† See p. 117.

less firmly. Its composition, in the thoracic duct of a dog, fed on animal food, is thus stated by Dr Prout:

Water, ...	89.2
Fibrin, ...	.8
Incipient Albumen, . . .	4.7
Perfect Albumen, . . .	4.6
Salts, ...	.7
	100.

The proportion of animal matter in the chyle from vegetable food is less.

Tiedemann and Gmelin observed, that the acidity of the mixed fluids of the intestines, which disappears in the course of the Ileum, re-appears in the Cæcum; and as there is necessarily a considerable delay in the passage of the contents of the bowels at this point, particularly in herbivorous animals, in which the cæcum is in general more developed than in man, it is probable that some fresh chyme is formed here, and partly converted into chyle as it passes along, and is absorbed from, the great intestines.

This observation is confirmed by Schultze, who farther asserts, that the use of the ileo-cœcal valve is to stop the descent of other contents of the small intestines, until the remains of the aliment last taken have been for some time stationary in the cæcum, and been acted on by the acid there; thus separating frequently bilious and alkaline matter at the end of the ileum from acid chyme in the cæcum.*

From the experiments of Magendie and Chevreul, it appears that oxygen and azote exist in the stomach during digestion; but that, in the lower intestines, the oxygen is found to have wholly, and the azote partly,

* Edinburgh Medical and Surgical Journal, Oct. 1835.

disappeared,—and that they are replaced by carbonic acid, hydrogen, and carburetted hydrogen, with sometimes a little sulphuretted hydrogen. It is still doubtful whether these gases have been in part secreted by the intestines; but it seems beyond doubt, that part of those which exist in the stomach must be absorbed in the bowels.

As the Chyle is mixed with the blood just before its entrance into the lungs, and is never recognised in blood that has passed through the lungs, it appears highly probable that a change takes place on it there, which completes its assimilation; and as nourishment of animal textures, of which azote is a constituent, may be effected without the use of any food known to contain azote, and as we have seen the possibility both of absorption and exhalation of azote at the lungs, and that fishes, which have less access to air than terrestrial animals, habitually absorb a quantity of the azote of the air they breathe,—it has been naturally conjectured, that the addition of azote from the atmosphere to the blood at the lungs, is a part of the process of assimilation there. The experiments of Marcet and Macaire, however, shew that even the chyle of herbivorous animals contains as much azote as that of carnivorous, and no satisfactory evidence of such an action habitually taking place at the lungs has been obtained.

The examination of the course of the lacteals, in all the vertebrated animals, and the experiments of Dupuytren and others, in which ligature of the thoracic duct (where that was single), was followed by rapid emaciation and death, leave no room for doubt that the main course of the chyle absorbed from the intestines, is through the Thoracic Duct to the Subclavian Vein. But on the other hand, that some admixture of the contents of the

lacteals with those of the bloodvessels takes place in the mesenteric glands, appears probable,—from the structure of these glands, formerly described,—from the change observed in the chyle by Tiedemann and Gmelin, after it has passed through these glands,—from streaks of white matter, resembling chyle, having been observed, particularly by the same physiologists, in the larger mesenteric veins,—and from the result of two experiments of Leuret and Lassaigne, in one of which a dog recovered after ligature of the thoracic duct, and no auxiliary duct could be discovered ; and in the other, after ligature of the vena portæ, blood was found in the Receptaculum Chyli, and lower part of the thoracic duct.

It is at all events certain that, during digestion, there must be a great increase in the quantity of fluid passing from the mesenteric veins into the vena portæ and liver, for two reasons, 1. Because, in the distended and excited state of the stomach and intestines, the quantity of blood entering these veins from the arteries is much increased. 2. Because much of the thinner fluids at least, received into the stomach, is absorbed by these veins.

But the branches of the vena portæ, within the substance of the liver, cannot be much distended ; and therefore it is to be expected that, during digestion, either the contents of the gastric and mesenteric veins, leading to the liver, will stagnate and distend these veins, or else, if their blood makes its way readily through the vena portæ and liver, that other branches of the vena portæ must suffer distention in their stead.

Now, there is no evidence of any great distention of the gastric and mesenteric veins themselves during digestion ; but it appears from the observations of Bichat, Sir E. Home, Dobson, Leuret and Lassaigne, and others, that

the *spleen* becomes obviously engorged with blood during that process, or even after copious draughts of liquids.

These considerations have induced Leuret and Lassaigne to think, that the chief use of the Spleen (which is known not to be of essential importance in the animal economy, as animals bear its extirpation without much inconvenience, but which is obviously an appendage to the stomach, intestines, and liver), is to suffer venous congestion, instead of the bowels themselves, during digestion, and thereby to allow the venous circulation through the liver to be equable and uniform, notwithstanding that the source whence the venous blood comes thither is liable to so great variation. And the very vascular and distensible structure of the spleen, the great size of the vein leading from it to the liver, and the correspondence of its diseases to those of the liver, may be stated as farther evidence in favour of this hypothesis.

Peculiarities have been observed both as to the blood of the splenic vein, and the lymph in the lymphatics leading from the spleen, which have been thought to indicate an influence of this organ in the assimilation of aliments; but although this is a probable supposition, there is as yet no decisive evidence of it.

It is important to be aware, that the time in which the process of Digestion is completed, and probably the amount of nourishment procured by it from a given quantity of food, vary considerably in individuals in perfect health.

We must not suppose that we understand the whole change which is wrought on the food taken into the stomach, when we have stated its chemical changes, and its course, up to the time when it is finally mixed with, and assimilated to, the blood. As we found that the blood possesses truly Vital properties, so we can have no doubt that, during the process of digestion, these properties are

communicated to a part of the nourishment taken, probably to that part of it which takes the form of *globules*.

The process of Digestion is much influenced by mental Emotions and Sensations; but no part of it is influenced by any Voluntary efforts of mind, from the time that the food enters the œsophagus, until its residue, unfit for assimilation, along with the biliary matter, and some part of the other secretions of the alimentary canal, arrives at the rectum.

The rectum is closed by the permanent tonic contraction of the sphincter ani, which is strictly a voluntary muscle, and the relaxation of the usual contracted state of which is within the power of mental acts.

When the sphincter is voluntarily relaxed, the peristaltic movements of the rectum, excited by its distention, suffice, in general, for the expulsion of the fæces.

The sensations which the feculent matter here excite, are more distinct than those excited by it in the higher parts of the canal. When felt more distinctly than usual, they give occasion, in the first instance, to an effort which is truly instinctive, by which the sphincter ani is forcibly closed, and their escape prevented; but when these sensations become intense, they excite, more directly, a contraction which is quite involuntary, of different and distant voluntary muscles,—viz. of the diaphragm, which descends as in inspiration,—of the arytenoid muscles, which close the glottis and keep the chest distended,—and of the abdominal muscles, which, acting against the contracted diaphragm and distended chest, forcibly compress the viscera, and aid the peristaltic movements of the rectum in expelling the fæces.

The influence of the sensation of the rectum in producing this movement is well seen in the tenesmus which results from the increased sensibility of the mucous mem-

brane of this part when inflamed, although little or nothing be passing along it.

The discharge of urine from the bladder is in like manner prevented, in general, by the tonic contraction of the levatores-ani muscles, and of those called acceleratores urinæ, and muscle of Wilson, (probably much more than of any of the fibres of its own muscular coat, which is strictly involuntary), and at times more forcibly restrained by voluntary contractions of these muscles, which compress the origin and first part of the urethra. The bladder is emptied, in ordinary circumstances, simply by voluntary relaxation of these, giving effect to the contraction of its own muscular coat, which is caused by the distention and irritation of its mucous membrane; but when the sensation resulting from distention of the bladder is intense, or when the sensibility of its mucous membrane is much increased, or the discharge of the urine difficult, the same simultaneous action of distant muscles is excited, as in the case of the rectum, to secure the forcible evacuation of the bladder.

When the function of Digestion is suspended by the denial of aliment, but thirst is allayed by drinking water, the consequences are, gradually increasing emaciation and debility; a sense of faintness takes the place of hunger; all the functions are performed slowly and imperfectly; the tunica conjunctiva of the eyes becomes inflamed (probably from the deficiency of secretion, and consequent action of the air on the membrane), and death takes place very gradually, at very different times after the last food was taken; but, in the human species, sometimes not until after forty days or more. Much longer fasting has no doubt been borne in some cases, chiefly by persons in whom the vital functions had been previously languid;

but the moral evidence of many reported cases of the kind is doubtful. After death the most remarkable appearances, besides the mere wasting and deficiency of blood in the vessels, are, the distention of the gall-bladder by bile (the flow of which is neither solicited, as in the natural state, by irritation of the mouth of the ductus communis choledochus, nor promoted by the distention of the stomach); the contracted state of the stomach and bowels; and frequently marks of inflammation in their mucous membrane; probably the effect of deficient secretion on that membrane, and consequent irritation by their contents.

The effect of total abstinence both from food and drink is to produce febrile excitement, perhaps a more active inflammation of mucous membranes, and subsequently a more rapid depression of strength, and death in less than half the time above stated.

CHAPTER XIII.

OF THE EXTERNAL SENSES.

Having completed the view of those functions which are concerned in the preservation of the organized frame, we proceed to a more detailed account of the strictly Animal Functions, which are connected with the Nervous System in the living body, and are manifestly the object of Nature in the construction of the animal machine.

The general conditions requisite for all the Sensations, viz. the circulation of arterial blood in the parts concerned, the presence of certain nervous filaments, and integrity of these up to the base of the brain, have been already stated. Some farther condition in the state of the Nervous System is certainly necessary, although it has not been detected; for cases frequently occur where, notwithstanding the presence of all those mentioned, the nerves of sense are unfit for their office.

The word Sensation is properly restricted to that kind of change in the state of the mind which immediately follows, and informs us of, an impression on any of the organs of sense. A little attention to what passes rapidly in the mind on these occasions, enables us to recognise the important distinction drawn by Dr Reid and others, between this change, in which the mind is truly *passive*, and the judgment we are immediately led to form of the external existence, and the notion we are often led to

form of the nature of the cause of the feeling which we experience, *i. e.* of the quality of some external object which it immediately suggests to us, and of which, through it, we have the *Perception.*

Various other mental acts connect themselves, even with some of the simplest acts of sensation; and as almost all sensations are either pleasant or painful, and many very fruitful sources of pleasure, they constitute a very important source of enjoyment, and motive to action. But at present we leave out of view these ulterior consequences of sensations, and confine ourselves to the enumeration of the different sensations themselves;—to a statement of the particular conditions under which the Nervous System is impressed in the case of each;—and to a short analysis of the inferences immediately drawn by the mind, touching the properties of external things, which are thus made known to it, or perceived by it. Some of these inferences are *natural* or intuitive, and others *acquired;* but the line of distinction between these classes of perceptions is not easily drawn.

In the lower animals, the mental acts excited by Sensation are much less numerous and diversified than in man; but the sensations themselves are often more acute; the pleasure immediately attending them probably equally intense; and certain immediate inferences from them, or Perceptions of the qualities of objects, more rapidly formed, so that the exercise of their senses requires less *education.*

A distinction was drawn by Dr Gordon* between Simple Sensations and Sensations of Emotion; the latter term being applied to certain feelings, exactly resembling those which may be produced by external agents,—distinctly referred to individual parts of the body, and often

* Heads of Lectures on Physiology.

attended with obvious physical changes there,—which cannot be traced to the influence of any external agents, but distinctly follow the excitation of certain mental emotions. This distinction is important, but the term Sensations of Emotion is not sufficiently comprehensive to include all those mental feelings, exactly similar to Sensations, which may proceed from internal causes only, independently of any impression from without on the organs of sense.

Simple Sensations are not so easily arranged into classes and genera as has been represented. Among the Higher or Special Sensations, felt only in consequence of impressions on individual organs, we should reckon not only those of Sight, Hearing, Taste and Smell, but also Hunger, Thirst, and the peculiar sensations of Anxiety at the lungs, already considered, and perhaps Nausea and Faintness; and the term Common Sensation should include not only what is commonly called Touch, but likewise the feelings of Heat and Cold, Pain, Itching; and another important class, which have been called Muscular Sensations, by which we are informed of the situation and extent of any muscular contractions which we voluntarily excite.

The individual sensations, referred to some of these genera, differ only in *degree;* but those referred to others have a manifest and original difference in *kind,*—as Colours, Visible and Tangible Figures, Smells, &c. The individual sensations referred to the heads of Common Sensation, Sight, and Hearing, have differences according to the *position* of the objects causing them; those belonging to Taste and Smell hardly differ in that respect. Those only which belong to Common Sensation and to Sight differ according to the magnitude or *size* of the objects that excite them.

Some curious observations have been made in observatories in Germany, shewing a manifest difference in the length of time occupied in exciting the Sensations of Sight and of Sound, by impressions on the eye and ear, in different individuals, and therefore indicating, that the change transmitted to the medulla oblongata, by which at least the latter sensation is excited, requires a perceptible length of time.* But the nervous action which excites muscular action, even when *reflected* from the sentient extremities of a distant nerve, appears from various facts to be instantaneous.

It is a general and important fact in regard to all sensations, that their intensity is very much influenced by Habit; they are felt strongly at first; and by continuance or repetition, at short intervals, the degree in which they are felt, and the portion of attention which they occupy, gradually diminish; and the emotions of pleasure or aversion which they occasion are not only blunted, but sometimes actually exchanged for one another. Impressions on the organs of Taste and Smell, which are at first unpleasant to most persons (*e. g.* those caused by tobacco or spirits), become gradually tolerable—then agreeable,—the want of them is felt as a painful privation,—and their cause must be applied in a gradually increasing degree, in order to produce the wonted effect. On the other hand, those causes which at first excite the most pleasant sensations, are successively followed by feelings of indifference, of satiety, and ultimately of disgust or aversion, if merely kept constantly before the organs of sense. In this respect there is a striking analogy between sensations and muscular contractions. A similar law, as we shall afterwards find, applies to the action of poisonous or medicinal substances, which likewise affect

* See Baly's Muller, p. 678.

strongly the nervous system, but without distinctly exciting sensation.

In considering in detail the different sensations, and the information they communicate, we treat first,

Of Common Sensation.

The physical conditions requisite for the sensations of this class, are merely these general conditions relative to the nervous system, which have been already stated, and the healthy state of the organization of the textures in which it resides.

The simplest form of common sensation is that to which the name of Touch is commonly given, which results from the mere apposition of any external substance on most parts of the body. These parts, from their susceptibility of sensation from that cause, are said to be endowed with Common Sensibility; and, from mechanical irritation carried to a certain length, they are affected with Pain. It appears from the elaborate experimental inquiries of Haller, that there are many textures in which this sensibility in the natural state is slight. Most of these are textures which have slight vascularity, particularly bones, cartilages, tendons, ligaments, fibrous membranes, even cellular and serous membrane. All these textures are, however, the seat of acute sensation in certain circumstances, *e. g.* the tendons and ligaments, when forcibly stretched, and the fibrous and serous membranes, when their vascularity is increased, particularly by inflammation.

The internal parts of the solid viscera appear to have less sensibility than their membranous coverings; and the greater part of the brain, and the nerves of the special senses, seem nearly destitute of common sensation.*

* Haller, Bichat, Wilson Philip, Flourens, Magendie, &c.

The parts which are absolutely insensible (*i. e.* all sensations commonly referred to which are really seated in the adjoining textures), are those which are not vascular, the cuticle, nails, hairs, and bony substance of the teeth.

The parts in which common sensibility is the best marked, and employed for the most useful purposes, are the skin and the mucous membranes; and especially the very vascular and nervous papillæ on the fingers and on the tongue. The sensibility of the skin is blunted, as its other vital functions are restrained, by the intervention of the cuticle; that of all these membranes is manifestly increased by any increase in the flow of the blood, and diminished by such causes as check the afflux of blood to them, *e. g.* by cold; that of the mucous membranes has the peculiarity of being apparently much less exalted by the state of inflammation than that of other membranes; perhaps because the capillary vessels of the mucous membranes, when distended by inflammation, are less compressed by adjoining firm textures than those of other membranes.

An experimental inquiry by Weber distinctly proves, that the Sensations of Touch are more distinct and precise, so as to enable the mind to perceive the distinction between two impressions made simultaneously on two points of the skin more clearly, in some parts of the body than in others. The parts which appear from these experiments to possess the most precise sense of touch are the tip of the tongue and points of the fingers, those possessing the least are the central parts of the body and limbs; so that the accuracy of the sensation appears to be nearly in proportion to the number of nervous filaments distributed to the part.*

The sensation of Pain varies considerably, according to

* See Baly's Muller, p. 700.

the different textures and parts of the body where it is excited. In many cases, its excitation may be referred, both in the healthy and diseased state, to the principle of mechanical pressure or irritation acting on sensitive nerves in one way or another: but there are other cases where the mode of its excitation is quite unknown. As residing in some parts, it is blended with the feelings of nausea and faintness, as from violent injury or disease of the abdominal viscera; and the effects which may be traced to this combination are of great importance in pathology.

The sensations of Heat and Cold are felt chiefly in the skin, distinctly in the mucous membrane of the alimentary canal, but hardly at all in that of the air-passages, in the lungs, or other viscera. Whether they are dependent on peculiar nervous filaments is still doubtful.

These sensations are remarkably dependent on the state of the capillary circulation on the surface, and more rapidly altered by changes in that respect than the actual temperature is. In consequence of the operation of causes which excite or strengthen the cutaneous circulation, cold is often little felt, when the temperature of the air in contact with the body is very low; and in consequence of the operation of causes weakening that circulation, it is often much felt when the temperature is moderate. These sensations are likewise peculiarly influenced by habit, and therefore dependent on the state of the temperature applied previously to the change which excites them; and farther, they are sometimes felt in consequence, not only of internal causes altering the state of the circulation on the surface, but of internal causes acting probably on the nervous system only, and unattended with any such perceptible effects. It is of importance to keep in mind these different causes, independent of the actual state of the

temperature, which influence the production of the sensations of heat and cold, when we speculate on the efficacy of these agents either in producing or counteracting disease.

The different sensations which we refer more strictly to the head of Touch, using that term as applied to feelings in which the mind is merely a passive recipient of impressions from without, belong only to two heads, Extension and Resistance; and by these we are informed, in some degree, of the magnitude, and of the hardness or softness, roughness or smoothness, &c. of objects.

There are differences, also, in the sensations of Touch, corresponding to the figure, and more especially to the position, on the sensitive surface of the body, of the objects perceived by this sense; but it seems to be only by experience that we learn to connect certain differences in our sensations, either with the particular figures of objects, or with the particular parts of our bodies on which impressions are made. These may be called, therefore, Acquired Perceptions of Touch, although founded on original differences of sensation.

The sense of Touch, without any active or voluntary effort, would probably suffice to convey to us the notions of extension or space, and of hardness or solidity, which are the essential elements in the idea we form of matter, and have therefore been called the Primary Qualities of Matter. But the information obtained in this way, particularly the knowledge thus acquired of Forms, would be very vague and imperfect. Our knowledge of these is acquired with much greater rapidity and precision, by the combination of the mere feelings of Touch, with the *muscular sensations*, already noticed, which inform us of the contractions of voluntary muscles, that are employed in moving the organs of Touch,—and of the degree and

extent of resistance, opposed to these movements of the organs of Touch, by the solidity, the figure, and the position, of tangible objects. It is by the number and variety of these muscular sensations which it can combine with distinct feelings of Touch, that the human hand is so admirably fitted for procuring information as to the size, form, weight, and character of the surface of external objects.*

These muscular sensations are likewise an important source of enjoyment, particularly in early life; their absence is a serious privation, and the effect of their excess is the uneasy sensation of Fatigue.

The distinction of the mere passive sense of Touch, from the combination of this with voluntary movements of the organs employed, made known by the muscular sensations that accompany them, is well stated by Magendie, in distinguishing the words Tact and Toucher; but the importance of the latter complex sensations to the acquisition of knowledge by the senses, is more fully illustrated by Dr Brown,†, than by any other author.

It is by this process that we acquire precise and accurate knowledge of the figures and other primary qualities of external things, and the process is necessary to correct the more vague and fallacious notions of those matters which we derive from Sight; but the information acquired, whether by the active or passive exercise, of the sense of Touch, is infinitely extended by means of Sight.

On comparing the feelings of Heat and Cold, with those sensations of Touch that communicate to us the notions of Extension and Resistance, and the mutual processes consequent on these different sensations, we per-

* See Sir C. Bell's Bridgewater Treatise.

† Lectures on the Philosophy of the Human Mind, Lect. 22, 23, 24.

ceive the distinction between what are called the Secondary Qualities of matter, which are *known to us only as the causes of certain sensations* (and of other effects in the inanimate world) ; and what are called the Primary Qualities of matter, of which *our minds form clear and definite notions, perfectly distinct from the sensations by which they are suggested ;* and which notions are the essential ingredients in the general idea that we have of the external world.

Both the primary and secondary qualities of objects are apprehended by us, in the adult state, and after long experience, as depending on causes external to ourselves, (see p. 179). But it is more difficult to determine in what circumstances it is, that the notion of external and independent existence is first formed in the mind, or what conditions are essential to its formation. Perhaps the mere repetition of any sensation,—and the conviction of want of power on our part to cause, or prevent, or in any way affect, that repetition, as long as the circumstances in which it was felt continue unchanged,—are enough to suggest that notion to the mind. Some think that it is only on apprehending the existence of the primary qualities of matter, that we form that general notion ; and Dr Brown endeavoured to shew, that the notion could not be formed, but for the muscular sensations, which accompany the active exercise of the sense of touch, and the interruptions which these experience from the resistance of external things.

The important fact, however, is, that by the exercise of the senses, and especially of this sense of Touch, which informs us of what we call the primary qualities of matter, we are naturally led, not only to form that general notion of external and independent existence, but also to form more particular notions of Extension, Form, Hard-

ness, Motion, &c. as qualities of external things, which *bear no resemblance whatever to the sensations*, through the medium of which we apprehend them. And one decisive proof of this being the true representation of this part of our mental constitution, is obtained by attending to the idea of extension or Space ; which is undoubtedly formed during the exercise (whether active or passive, is immaterial at present) of the sense of touch ; and is no sooner formed than it " swells in the human mind to Infinity ;"—to which, certainly, no human sensation can bear any resemblance.*

Of Smell and Taste.

The Sensations of the Nose and Mouth may be considered together, on account of the intimate connexion which will appear to exist between them.

In order that the sensation of Smell may be felt, the only special conditions necessary are, *first*, the passage along the internal nares, of air impregnated with certain effluvia which are believed to arise from many substances, but which manifest their existence in no other way than by the sensations they thus excite ; and, *secondly*, the healthy condition of the mucous membrane which lines the ossa spongiosa and other parts of the internal surface of the nostrils, especially, as it would appear, of the upper and middle meatus, where the 1st nerve is chiefly distributed. That some particular condition of the membrane is necessary to the sensation appears from the fact, that, unlike common sensation, it is diminished or lost in consequence of inflammation of the part ; but the nature of this particular condition is unknown.

* See Reid's Inquiry into the Human Mind, chap. v. sect. 3–7 ; and Stewart's Elements of the Philosophy of the Human Mind, chap. i. sect. 3. and 4.

It is necessary to distinguish between the special sensations, which odoriferous substances only can produce, and the sense of irritation in the nostrils, which any acrid or stimulating vapour or powder will occasion. The latter is the immediate cause of sneezing ; and it has been proved by the experiments of Magendie,* confirmed by observations in some paralytic cases in the human body, that the sensibility to such irritation depends on the fifth nerve, and continues after the 1st or Olfactory nerve is destroyed by injury or disease. It appears also, that by section of the 5th nerve, the sense of smell, as well as others of the special senses, is blunted or perverted. But the distribution of the 1st nerve to the parts concerned in this sense, and to no other ;—its greater development in proportion to the size and complexity of the organ of smell, in animals in which this sense is more exquisite ;†—some cases on record, in which the sense of smell was lost in consequence of disease of the origin of the 1st nerve, while the 5th was healthy ; ‡—and the appropriation of the 5th nerve to common sensation in other parts ;—seem sufficient to shew that the 1st nerve is that most essentially concerned in the sense of Smell, properly so called.

This sense informs us only of the different varieties of a single secondary quality of matter, to which the term Odour is properly applied, existing only in certain bodies, and which extends itself, by an unknown medium, to some distance from them.

The sensation of Taste is commonly described as that which results from the contact of certain bodies, called Sapid, with the upper surface and tip of the tongue, inside of the gums, and palate, especially when rubbed forcibly

* Journal de Physiologie, tom. iv.

† See Serres, Anat. Comp. du Cerveau, pp. 281 and 286.

‡ Serres, p. 294.

between these; and which is aided by the action of the fluids of the mouth.

In the case of this sense likewise, we should distinguish the component parts of the complex sensation felt on such occasions. The sensation which informs us of what is strictly called the Flavour of any substance, is at once distinguished as bearing a strong resemblance to smell; and the following facts seem sufficient to prove that it is in fact the sensation of smell, produced by effluvia from the substance held in the mouth passing through the nostrils during expiration.

1. When the mucous membrane of the nostrils is inflamed, the flavour even of sweet, bitter, or acid substances is not perceived, although there be no symptoms of disease in the mouth, and all the other sensations felt there are natural.

2. By carefully inspiring, during the whole time when a sapid substance is held in the mouth, or by carefully expiring through the mouth only, its flavour may be rendered imperceptible, even though it be rubbed repeatedly between the tongue and palate; a sense of what is usually called irritation or pungency, more or less acute, according to the nature of the substance in the mouth, only remaining; but, on the slightest expiration through the nostrils, the true flavour becomes immediately distinct.

When the various sensations which appear from these facts to belong strictly to the sense of smell, are carefully distinguished from the others, which are felt in the mouth, although these last may appear both acute and peculiar, it seems very doubtful whether they amount to more than very fine sensations of touch, produced chiefly by fluid substances penetrating the papillæ of the tongue. They hardly appear to merit the title of a special sense, any more than those feelings in the nostrils which prompt to

sneezing, or those in the larynx which prompt to coughing. And accordingly, it will be observed, that there is no special nerve for the sensations in the mouth, the papillæ of the tongue having their nervous branches from the third part of the fifth.

The mixed sensations, probably referable to the heads of Smell and of very delicate Touch, which have their seat in the nostrils and mouth, are not only the occasion of much enjoyment, but have evidently two important uses, in reference to the function of digestion: 1. To excite the flow of the mucus and saliva, which are to aid in preparing the food for the action of the stomach: 2. To inform us of qualities in the objects that excite them, which bear a certain, though not a uniform, relation to their fitness for digestion.

Of Sight.

It is here necessary to recall to recollection the structure of the principal parts constituting the organ of sight; first, the protection given to the eyeball by the eyebrows and eyelids, and the lubrication of its surface by the tears descending from the lachrymal gland, and also by the thin mucous fluid that exudes from the tunica conjunctiva: next, the different coats of the eyeball; the conjunctiva covering its fore part; the firm and strong sclerotic coat, which bounds and encloses the essential parts of the organ, and connects itself, in front, with the prominent and transparent cornea; the vascular and opaque choroid coat, terminating in front in the annulus albus at the root of the iris, and in the ciliary processes behind the iris; and within it, the nervous expansion called the Retina, covered externally by a very delicate cellular membrane, and internally by an equally delicate vascular one, and the concave surface of which is spread over the

thin membranous capsule that contains the Vitreous Humour; in front of which humour, the coats of the eyeball enclose the dense transparent Crystalline Lens, and the thin aqueous humour, divided into two compartments by the opaque and coloured iris: lastly, the entrance of the optic nerve, and its expansion to form the retina, on the inner side of the axis of the eye,—its passage through the sphenoid bone, and within the cranium, to the place of its union with its fellow on the opposite side,—and its winding course across the crus cerebri and along the lower and outer edge of the thalamus, till it reaches the corpus quadrigeminum.

The aqueous and vitreous humours of the eye contain about 2 per cent. of animal and saline matter, and the crystalline lens, which is solid, and denser towards its centre than on its exterior, contains 42 per cent. of animal matter and salts.

In order that the Sensations enabling us to perceive light and colour should be felt, the only special condition probably is, that Light, by which we mean the external cause of these sensations, should impinge on the retina. But in order that this light should give any distinct information as to the form or other qualities of the objects whence it comes, it is necessary that it should be so affected by the coats and humours of the eye, as to form a distinct image of these objects on the retina at the bottom of the eye.

That such images of external things are really formed on the Retina, has been shewn, by fixing the eye of an animal just killed in a small aperture of a darkened room, stripping off carefully the opaque sclerotic and choroid coats at its back part (or, in the case of albino animals, without that preparation), and inspecting the posterior surface of the retina. Magendie was even able

to shew, in such experiments, by drawing off successively the different humours, the importance of each of these in the formation of the images.

In order to understand how this is effected by the eye, it is necessary to attend to the following optical propositions, the truth of which is known, partly by experiments, and partly by mathematical deduction from principles which experiments had established.

1. When light passes through any single transparent medium, it moves always in straight lines.

2. When it passes from one transparent medium to another, unless it falls perpendicularly on the surface where they join, it undergoes a change of direction, or is *refracted;* and we judge of the mode and degree of its refraction, by supposing a perpendicular drawn to the surface of junction of the two media, at the point where the ray quits the one and enters the other, and observing whether, in its course through the second medium, its change of direction is towards, or from, that perpendicular. If it be refracted towards the perpendicular, the medium which it enters has the *greater refractive power* of the two; but if from the perpendicular, it has the *less refractive power.* The angle which the incident ray makes with the perpendicular is called the Angle of Incidence, and that which the refracted ray makes with it the Angle of Refraction; and the greater the difference between these two, the greater the difference of refractive power of the media.

3. On comparing the course of rays which fall with *different degrees of obliquity* on the surface of function of the *same media*, it is found that the refractions they respectively suffer bear a certain proportion to the degree of their obliquity; the sine of the angle of incidence ha-

ving to the sine of the angle of refraction always the same ratio.

4. Denser bodies have, in general, a greater refractive power than rarer; and accordingly, water, glass, and the transparent parts of the eye, have a greater refractive power than air.

5. When a ray of light passing through air falls obliquely on a convex lens of glass (*i. e.* a piece of glass bounded on each side by a segment of a sphere), or of any other transparent matter of greater refractive power than air, it necessarily undergoes one refraction where it enters, and another where it leaves the lens, and each of these brings it nearer to the axis of the lens,—*i. e.* to the straight line which joins the centres of the two spheres, segments of which bound the lens.

6. When different rays, coming from the same point, and traversing air, fall on such a lens, and each, after the two refractions it undergoes, is brought towards the axis of the lens, the point of that axis towards which they tend is determined very nearly by three conditions,—by the distance of the point from which they come,—by the degree of convexity of the surface of the lens,—and by the degree of its refractive power, that is, by the proportion of the sine of the angle of incidence, to the sine of the angle of refraction, of all rays that enter it from air. Now, these three conditions are the same in regard to all the rays that issue from any one point; and therefore, if the refractive power be such as to bring any one ray from that point to intersect the axis of the lens, it will bring all the rays from that point to intersect the axis at the same place; *i. e.* it will concentrate all the rays from that point into a *focus* beyond the lens.

7. Every double convex lens in this manner draws together into a focus all parallel rays, *i. e.* rays coming from

a point at an infinite distance; and the fixed point to which these tend is called the principal focus of the lens: And farther, every such lens draws together into a focus all the rays coming from any point more distant from itself than its own principal focus; the rays from a point at the distance of that focus become parallel after passing through the lens; and those from a point nearer than that, diverge after passing through the lens, although in a less degree than before entering it.

8. As a convex lens concentrates all the rays from a distant *point* into a *focus*, so it concentrates all the rays from a distant *object* into an *image*, which will be nearer the lens, and smaller, as the object is the more distant, and the refractive power greater; and which will be *inverted* and reverted, because the rays from any point of a luminous object, lying on either side, either of the vertical or horizontal plane, that passes through the axis of the lens, must necessarily cross that plane, after the two refractions they suffer, before they can be concentrated.

Now, in the eye, although the apparatus is more complex, yet the effect on light from a point, or from an object placed before the eye, is necessarily the same, as would be produced by a double convex lens. The ray which falls from any luminous point perpendicularly on the centre of the cornea, and passes through the axis of the eye, undergoes no refraction. All other rays coming from the same point, and forming a long narrow cone of light between it and the pupil, are refracted, first where they enter the cornea and aqueous humour,—then where they enter the crystalline lens, which has the greatest density and refractive power,—and lastly, where they pass from the crystalline into the vitreous humour. All these refractions are towards the axis of the eye, and these

rays meet the one that passes along the axis in a focus. And as the humours of the eye draw together all the rays entering the pupil, from a luminous point placed before it, into a focus, so they draw together the rays from an object, or set of objects, into an image, which is necessarily placed *somewhere behind the crystalline lens*, and is *inverted* and reverted.

In the usual and natural state of the eye, its transparent parts are fitted, by their refractive power, for concentrating parallel rays (or rays from a point at an infinite distance), just at the Retina, *i. e.* the *principal Focus of the eye lies at the Retina*, and therefore clear and definite images of very distinct objects, the rays from any single point of which are almost exactly parallel, are formed on the retina, and the eye is fitted for the vision of these distant objects. And as the divergence of the rays which come from a single point, even a few feet distant from the eye, and fall on so small an area as the pupil of the eye, is very trifling, the eye is equally fitted, in its natural state, for all practical purposes, for the distinct vision of all objects situated more than a few feet from it.

But in the natural state of the eye, after it has been employed in distant vision, when an object is brought within a few feet of it, the rays from that object converging to form an image beyond the retina, it is at first seen indistinctly, and an effort is voluntarily or instinctively made, by which the eye adjusts itself to the distinct vision of this object; and if it be brought still nearer, the eye may be made to continue this effort of adjustment, till it come within about five inches of the eye; after which, the refractive power of most eyes is insufficient for bringing together the rays on the retina, and the object is again seen indistinctly.

The effect by which the eye increases its refracting

power, and adjusts itself to the distinct vision of an object thus approaching it, may be observed to be attended with a contraction of the pupil; and Dr Brewster found, that the application of bright light to the eye, whereby a sudden contraction of the pupil is effected, causes the eye to adjust itself to vision at a shorter distance than previously;* and Dr Wells shewed, that when the iris is palsied, as by belladonna applied to the eye, the power of adjustment to distances is lost.† But the mere elongation or shortening of the iris, although it alters the size of the cone of light passing from any luminous point to the pupil, and therefore alters the illumination of the image formed at the back part of the eye, does not alter the refractive power of the eye. The adjustment of the eye must therefore be produced by some other change, contemporaneous with the contraction of the pupil.

The manner in which this is done is still uncertain; but the most probable supposition is, that it is by a vital contraction of the annulus albus, or ciliary ligament at the root of the iris, simultaneous with the contraction of the sphincter iridis, and which will have the effect of increasing somewhat the convexity of the cornea.‡

The usual movements of the iris (probably of its sphincter muscle, though that is not easily demonstrated) are caused by the impression of light on the retina, and are consequent on, or at least intimately connected with, the sensation of light felt in consequence of that impression. When the light is diminished the pupil expands, the cone of light coming from any one point to it is en-

* Edinburgh Journal of Science, vol. i. p. 77, 1824.

† Philosophical Transactions, 1811.

‡ See Knox, in Transactions of Edinburgh Royal Society, vol. x., and Brewster, in Edinburgh Journal of Science, vol. i. 1824.

larged, and the focus of that point (or the image of an object of which it makes a part) is rendered more luminous than previously; and the reverse change happens when the light becomes more intense; so that this is a moveable curtain, placed before the eye to regulate the quantity of light admitted into it, and moved by the very sensations which call for its intervention.*

Accordingly, Mr Mayo found that the iris could be made to contract, either by irritation of the optic nerve, within the cranium of a bird, or by irritation of the third nerve, which is the only certainly motor nerve that sends filaments to the ophthalmic ganglion, whence the ciliary nerves, passing to the iris, are derived, and in the human body, palsy confined to the 3d nerve is attended with immobility of the iris.†

The experiments of Magendie and others have shewn, however, that the 5th and Sympathetic nerves, which also send branches to the ganglion, are concerned in those movements, the pupil being either enlarged or contracted, and rendered nearly immoveable, by section of these nerves in different animals.

The orbicularis oculi muscle, which closes the eyelids, and has been shewn by Sir Charles Bell to be moved by filaments of the portio dura, is also obedient to the sensation of light, when that sensation is so intense as to require the complete removal of its cause to prevent acute suffering, and injury of the retina and optic nerve.

The aperture of the pupil obviously admits rays of light only to a part of the concave expanded surface of the retina, and this illuminated part is further diminished when the pupil is contracted. Accordingly, the *field*

* See Whytt on the Vital and Involuntary Motions, sect. vii.

† Anatomical and Physiological Commentaries, No. II.

of vision, when the eye is kept at rest, is very limited. According to the observations of Dr Young, it extends upwards to objects situated in a line forming an angle about 50° with the optic axis, downwards to 70°, inwards to 60°, and outwards to 90°.

But it is farther obvious, on attending to what is seen when the eye is fixed on a single object, that the field of *distinct* vision is much more limited than this; any object situated in a line which makes an angle of 5° with the optic axis, is seen very indistinctly.

From this we learn, *first*, the importance of the muscles of the Eyeball, by which the eye is easily moved, voluntarily or instinctively, so as to bring its axis to bear on any object that is to be examined, and secure distinct vision of it; *secondly*, the peculiar sensibility of that portion of the organ which lies in the axis of the eye, exactly opposite to the pupil.

Just at this point there is found, in the human eye, and in certain animals, whose vision is very acute,* the central foramen, or opening in the retina; the dimensions of which, after death, are such, that it would seem that the images which give the most distinct vision must be formed within it.

How the change in the optic nerve, necessary to the sensation of sight, should be produced by an impression, thus apparently made on a point, which the nervous filaments do not themselves reach, it is at present impossible to explain; it may be conjectured, however, that this open space is left for the elongation or *erection*, during the exercise of the eyes, of those nervous fibres by which the most distinct vision is produced, and is therefore filled up at the time when such vision is going on. The observation should perhaps be connected with another, viz.

* See Knox, in Edinburgh Phil. Trans. vol. x.

that in many birds, reptiles, and fishes, which are endowed with a more penetrating sense of sight than ours, an empty space is in like manner found at the other extremity of the filaments composing the optic nerve, viz, in the Corpora Quadrigemina.*

Another peculiarity in regard to the sensibility of the retina is, that those rays of light which are concentrated on the part, on the inner side of the optic axis, where the optic nerve enters, are found to cause no sensation; as is easily proved by fixing the right eye on two small objects placed together on a plain surface, then moving the one of these objects gradually to the left, and keeping the axis of the eye directed towards it, while the attention is fixed on the sensation communicated to the other object; the existence of the insensible spot on the retina is then quickly discovered. It has been conjectured that this depends on the entrance, not of the optic nerve, but of the central artery of the retina which it encloses.

The experiments of Flourens have unequivocally shewn that, in many of the lower animals, the Corpora Quadrigemina, where the optic nerves originate, are the only parts of the larger masses of the Nervous System concerned in the mere sensations of the eye.†

What has been said of the conditions in the eye, necessary to vision, sufficiently explains most cases of blindness; and likewise enables us to understand the nature of the imperfections of this sense called Presbyopia and Myopia. In the former, the eye has generally become somewhat flattened, and has lost somewhat of its refractive power, so that the images of near objects, seen by diverging rays, are formed a little beyond the retina; and a convex lens is useful, to diminish the divergence of

* Serres, Anat. Comp. du Cerveau, pp. 197 and 304.

† Recherches Experimentales, &c. p. 150.

such rays before they enter the eye,—cause them to converge sooner in passing through it,—and thereby render the images they form on the retina definite and distinct. In the latter, the eye has generally a more convex form, —has an excessive refracting power, so that it is naturally adjusted to the distinct vision of near objects;—and its focus of parallel rays, by which distant objects are seen, being a little in front of the retina, these are seen indistinctly; unless a concave lens is employed, to give a little divergence to the rays coming from them.

These are the most important principles that have been ascertained relative to the conditions, in each eye, necessary to distinct vision. But in general both eyes are employed; and the condition which is necessary, in order that an object, at any distance, may appear single, although an image of it is formed in each eye, appears to be merely this, that the axes of the two eyes shall be fixed on the same point of the object; for which purpose, the motor nerves and muscles of the eyeball instinctively act together, even from the time of birth. The necessary effect of this is, that the rays coming from all the points of the object in question, are concentrated upon *corresponding points* of the retinæ of the two eyes; that is, upon points similarly situated in regard to the centres of the retinæ of the two eyes; and experience shews that, in these circumstances, objects are seen single, but that, when their images are not formed on corresponding points of the retinæ, they are seen double. Of this there are several simple proofs. 1. When the axes of the eyes are fixed on a near object, and the attention at the same time directed to a distant one, this last, the image of which cannot be formed on corresponding parts of the two eyes, is seen double, and *vice versa*. 2. When pressure is made on the ball of one eye, so as to prevent its axis from

being directed to the same point as the axis of the other, any object that may be looked at is seen double; and the same occurs in Squinting, or distortion of the eyes, although, as in most of these cases, the sensibility of one eye is much feebler than that of the other, one image only is usually made an object of attention. 3. When two distinct objects are placed carefully in the lines of the axes of the two eyes of a person who squints, or whose eyes are distorted, as their images are necessarily formed on corresponding points of the retinæ, they are seen to coincide. 4. When two objects are held close to the two eyes, and exactly in their axes, as the optic axes cannot be directed to the same point in either of them, and as their images, although necessarily very faint from their proximity to the eye, must fall on corresponding points of the retinæ, so they are seen, although indistinctly, yet evidently as coinciding.*

It was conjectured by Newton, that single vision may depend on a semi-decussation of the optic nerves at their commissure, whereby the right half of each retina might be in communication with the right hemisphere of the brain, or right side of the corpora quadrigemina, and the left half of each with the left side; the consequence of which may be easily conceived to be, that the *corresponding points* in the retinæ of the two eyes may be connected with, and their sensibility depend upon, *the same points* in the cerebro-spinal axis. Different anatomists have agreed as to the semi-decussation of the human optic nerves; and Dr Wollaston has supported the theory, by reference to the known fact, that, in a diseased state of

* See Reid's Inquiry into the Human Mind, ch. vi. sect. 13. The objections stated to Reid's principles on this subject by Dr Wells (Essay on Single Vision), seem to be founded on misconception.

vision (the suffusio dimidians, generally transient, but sometimes permanent), one-half of each retina is insensible to the light at the same time;* and therefore, although both eyes are open, one-half of the field of vision is unperceived. This theory is quite in accordance with the comparative anatomy of the optic nerves, a semi-decussation being found in the human body,—a partial decussation in most mammalia and birds, which usually regard objects with one eye only, and direct the axes of both to single objects only when these are at a great distance;—and the decussation being complete in most reptiles and fishes, which probably never regard any object with both eyes at once; but partial, again, or even similar to the human, in certain fishes, which direct both eyes frequently, or habitually, to the same points.† But in order to have complete proof of the theory, it would be necessary to have more precise information as to the disposition of the nervous fibres, both at their extremities in the retina, and at their origin in the corpora quadrigemina, than has been yet obtained.

It has been stated by opticians, as the law of Visible Direction, that every visible point appears to be in the direction of a perpendicular erected on the retina at the point where the rays issuing from it are concentrated. Our seeing objects erect, although the images they form are inverted, is a part of this general law, and it is further illustrated by the following fact. If a small object, brightly illuminated, be held within an inch of the eye, and inspected through two very minute holes, set close to one another in a card, two faint images are formed of it (by rays already converging before they reach the eye, and which do not cross the axis before reaching the reti-

* Phil. Trans. 1824.

† See Solly on the Brain, &c. p. 243.

na), on different points of the retina; and it is seen double, although by a single eye, and, by closing one or other of the holes in the card, it is found that the image which appears uppermost is formed by rays which pass through the lower hole, and therefore is formed on the lower part of the retina, and *vice versa.**

This principle has been generally held to be an ultimate fact on the subject; and to be the only admissible explanation of the accordance which exists between the intimations of sight and touch as to the position and form of objects, which are perceived both by sight and touch, notwithstanding that the impressions made on different points of the retina, by the parts of such an object, are in the reverse order of those made on different points of the skin. But if we observe the course of the tractus optici turning round the crura cerebri, and the mode of their implantation into the corpora quadrigemina, it seems pretty clear, that the impressions made through the optic nerve and tractus, on the cerebro-spinal axis, by the different parts of an object, must be in the same order as the impressions which these make on the skin; and, therefore, that while the semi-decussation of the optic nerve explains single vision by the two eyes, the contorted course of the optic tractus explains erect vision by inverted images.

But another question here presents itself: If the *right* corpus quadrigeminum (or optic lobe) is appropriated to the correct perception of the *left* half of the field of vision, and both eyes are used at once, how is this *left* half of the field of vision felt to correspond to impressions on the *left* side of the body? The answer appears to be, that the left side of the body feels only by impressions made through it on the *right* side of the brain, or medul-

* See Reid's Inquiry, &c. chap. vi. sect. 12.

la oblongata, above the decussation at the pyramids. This appears, from Pathology, to be true, even as to impressions made on the left side of the face or head, and felt through the fifth nerve, which arises above the decussation. According to this doctrine, the use of that decussation is, to keep tactual impressions on the left side of the body, in harmony with the visual impressions from the left side of the field of vision, which, by the laws of light, are necessarily made on the right side of each retina, and therefore on the right optic lobe; and *vice versa.* Accordingly, the decussation at the pyramids appears to coincide, in the animal creation, with the partial decussation of the optic nerves, being found in mammalia and birds, but not having been observed in fishes or reptiles. In these last, the decussation of the optic nerves is generally complete, and all the left half of the field of vision is seen only by the right optic lobe; but then, the two eyes being incapable of direction to the same object, the right and left portions of the whole field of vision are probably never made objects of simultaneous attention; and therefore no contrivance is required to secure that these two great divisions of the visible world should appear in their true relation to each other; we may suppose that in them it is sufficient that the different parts of each should, by the arrangement of each optic nerve, be presented to the sensorium in harmony with the perceptions of touch.* But in order to confirm this theory, it would be requisite to find a decussation at the pyramids in those fishes which have a partial decussation of the optic nerves.

The images formed on the retina certainly differ as to colour, as to illumination, as to size, form, and position; and it is obvious that, in the adult state, the different

* See a paper by the Author, in Edin. Phil. Trans. vol. 13.

sensations they excite not only inform us as to light and colours, but also as to the size, forms, position, and distance of objects. But it is difficult to judge how far the notions on these last points, which we connect with them, in the adult state, are simply dependent on them, or how far they are acquired by the sense of touch, and only suggested by the sensations of the eye, in consequence of experience, and association with those of touch.

The notions we have of the brightness, and of the colours of objects, are necessarily and entirely dependent on the sensations of sight. The colour depends on the part of the compound ray of light which each object reflects or transmits; and the perception of it depends on a peculiar sensibility of the optic nerve, which is not enjoyed, in an equal degree, by all men. of perfectly distinct vision in other respects.*

The forms of the images of external things, which exist in the eye, differ so widely from their real forms, that we should probably not be able to acquire the notion of any complex form by this sense, unassisted by the sense of touch. Neither is it possible that the differences of sensation, that correspond to the differences of

* It has been long known, that there are many persons who cannot distinguish accurately a colour from its complementary colour; *i. e.* from that which the other colours in the spectrum united together will produce. Thus the distinction of red from green is hardly perceptible to many. Sir David Brewster has given what appears a satisfactory explanation of this fact, by discovering, that in all parts of the coloured spectrum, there are rays which have escaped decomposition. To a person, to whom one of the prismatic colours is imperceptible, all colourless objects being seen by means of rays of the other colours only, will necessarily appear of the colour complementary to that, which is invisible to him; and objects of that unperceived colour being seen by the undecomposed or colourless light, will of course have to him that complementary colour also.—See Edin. Phil. Journal, 1831.

the magnitude and position of objects, can suffice to inform us of their real size or real position. And the distance of any object from the eye, being measured by a straight line drawn from it, which, to the eye, must appear as a point, cannot, of course, be a direct object of sense. Nor can any reasoning, on the mere sensations of sight, furnish just conclusions as to these points. All these are, therefore, usually considered as Acquired Perceptions of Sight; *i. e.* it is supposed to be by experience, and by comparison with the information acquired by the sense of touch, that we learn to associate the differences, in these respects, of the sensations we feel, with the actual circumstances of the external objects from which they proceed; and some have supposed that it is only in the same way that we learn that objects, seen by inverted images, are really erect, and even that we learn to distinguish the numbers of visible objects.

In the instances of persons blind from infancy, who were restored to sight by Mr Cheselden,* Sir E. Home,† and Mr Wardrop,‡ it appeared that the notions of position, form, distance, and size of objects, suggested by the newly acquired sense of sight, were very imperfect and erroneous. We can observe, even in the adult state, that our ideas of form and position are much aided and corrected, if not acquired, by touch; and our ideas of the latter by the muscular sensations which accompany the actions necessary to fix the optic axes on any object of sight; that the judgment, as to size, from sight, is dependent on a previous judgment of distance; and that our estimates of distance are very liable to error, and are assisted, if not acquired, by help of different kinds of experience,—by the effort made to adjust the eye to distinct

* Philosophical Transactions, vol. xxxv.

† Philosophical Transactions, 1807. ‡ Ibid. 1826.

vision, when the object is very near,—by the degree of inclination of the optic axes requisite to fix both eyes on it, when it is rather more remote,—by the degree of vivacity of its colours,—by the distinctness of its minute parts,—and more especially by the number, and the known size, of intervening objects.

But although it is certain that a *great part* of our judgment on these points, connected with the sensations of sight, is really acquired by experience and education, we should not hastily conclude, that the differences in our sensations, corresponding to these circumstances of external objects, may not suggest to us, even prior to experience, *some part* of the conclusions which we habitually draw from them. For we know that many of the lower animals form, and act on, correct judgments of the position, size, and distance of objects, immediately on coming into the world; and that we ourselves, in various other instances, both act instinctively, we know not why; and acquire knowledge intuitively, we know not how.*

* Dr Brown makes the following observation on objects being seen single and erect, by means of two inverted images on the retina. "If the light reflected by a single object, touched by us, had produced not two only, but two thousand separate images, erect or inverted, the visual feeling thus excited, however complex, would still have *accompanied the touch of a single object;* and if only it had accompanied it *uniformly, the single object would have been suggested by it,* precisely in the same manner as it is now suggested." But is it not a sufficient answer to this doctrine, at least as far as regards single vision, to observe, that to a man who has a permanent squint, or distortion of the optic axes, the visual feeling always suggests double objects, although he knows, by touch, that they are single? This fact proves, that there are conditions in the eyes themselves, and probably also, as stated above, in the optic nerves and brain, essential to single vision; and consequently, that it is *not merely* by means of *the sense of touch* that we are led to a correct judgment on that point.

Of Hearing.

In examining the organ of this sense, we see indications of much contrivance, the uses of which are not understood, because the laws of the transmission of sound are not so well known as those of the transmission of light; and therefore it is to no purpose to enlarge on them.

The condition necessary to the sensation appears to be the communication of certain vibrations, of which many substances, in different degrees, are susceptible, to the branches of the auditory nerve which are spread over the different parts of the labyrinth; these vibrations may be transmitted by the bones of the head, as when a sounding body is placed between the teeth; but in order that impressions may be received by this sense from a distance, through the medium of air, the contrivance employed is complex; the vibrations of the air, derived from the sounding body, are first communicated through the meatus externus, which is lubricated by its oily secretion, the cerumen, to the outer chamber, or tympanum,—which is closed by a membrane where the impression is made on it, but filled with air from the posterior nares,—which is extended, in a very irregular form, into the mastoid process, and traversed by a chain of minute bones (furnished with muscles whereby they are, to a limited extent, moveable), one of which is fitted to the aperture that leads to the inner chamber or vestibule. This cavity is filled with a liquid like the aqueous humour of the eye, and communicates with different small winding canals, situated in the interior of the hardest bone in the body, and the membrane lining which is supplied, by many minute holes in the bone, with very numerous small

branches of the portio mollis of the 7th pair of nerves. The whole of these cavities and canals, containing the fluid, have been generally thought to be the seat of this sense; but the experiments of Flourens, shewing that injury or destruction of the semicircular canals injures other functions indeed, but apparently not the sense of hearing,* render it probable that those parts of the 7th nerve only which supply the cochlea and vestibule, are essentially concerned in this sense.

Comparative Anatomy shews, that a shut sac, containing a fluid, and lodging the extremities of the 7th pair of nerves, is all that is essential to constitute an organ of hearing throughout the animal creation.†

The importance, in our species, of the different parts of the organ of hearing is shewn by deafness resulting,— 1. From hardened wax in the air-passages: 2. From closing of the eustachian tube, which conveys air to the tympanum: 3. From separation and discharge of the small bones, and consequent discharge of the liquor from the labyrinth: 4. From disease of the 7th nerve, or of the adjoining parts injuring that nerve. And in the case of this sense, as well as of sight, there are also examples of its total deficiency even when all parts of the organ appear naturally formed, believed to be owing to some imperceptible defect in the 7th nerve, or its origin in the floor of the 4th ventricle.

The individual sensations of sound differ from one another, not only in intensity or loudness, which depends on the length of the vibrations of the body whence the sound proceeds, but also in two other particulars, which are peculiar to them, viz. Tone and Timbre.

The tone, or pitch, of a sound, depends on the num-

* Ann. des Sciences Naturelles, tom. xv.

† Cuvier, Leçon 13. Breschet, Memoire sur l'Audition, &c.

ber of vibrations performed by the sounding body in a given time, being lower as these are less numerous, and higher as they are more. According to the observations of Dr Wollaston,* there are some persons who are totally insensible to certain very acute sounds, although they have the usual sensibility as to lower sounds.

The timbre of sound depends on the nature of the sounding body, and varies in every different musical instruments, although the note struck is the same. There are other differences in sounds, which cannot be so easily reduced to classes or genera.

Sensations of sound differ according to the direction of the sounding body, although it is difficult to understand how differences in this respect should reach the auditory nerves so as to affect them. The same sound coming from points, the directions of which from the ear make an angle of 10° to 12°, is felt to differ; but it is probably from experience only that we learn to connect these differences with the true directions of objects.

Our judgment of the distance of objects by means of this sense, is founded only on the intensity of the sound; and the intensity that corresponds to each distance is known by experience only, which renders the judgment liable to error. We know, for example, by experience, the ordinary tone and loudness of conversation at ordinary distances. When, by reflection of sounds from concave surfaces, the same tones are heard louder than usual, we judge the distance of the speaker to be less than the reality; and in the state of syncope, when the same tones are heard fainter than usual, we judge the distance to be greater than the reality.

Those persons who can articulate distinctly during inspiration, produce sounds which have nearly the same

* Philosophical Transactions, 1820.

tones as are heard in ordinary conversation, but are much more faint, and therefore deceive us as to distance; and this seems to be an essential part of the art of the ventriloquist. But he has no such means of imitating those differences of sensation by which we judge of the direction of sounds; and can only attempt that by misleading the imagination.

What is properly called a Musical Ear differs from the mere perception of minute differences of sounds, and recollection of their successions; and is characterized by the pleasure those possessing it derive from certain successions of sounds only; and by immediate observation of any deviation from the successions fitted to give this pleasure. The circumstances of organization on which it depends are quite unknown. By the habit of minute attention to the differences of sounds, it is susceptible of much improvement; but the pleasure derived from it being complex and much connected with associations, is probably by no means strictly proportioned to the degree of accuracy in which it is possessed.

Before leaving the subject of the external senses, it is right to mention the cases, in which causes internal to the body produce sensations, exactly similar to those generally produced by impressions from without.

Hunger, Thirst, Anxiety from the want of air in the chest, most cases of Pain, and other internal sensations, depend on causes internal to the body, but external to the nervous system; but there are some cases of very intense pain in which there is no evidence of any cause, external to the nervous system itself. And there are two sets of well-known phenomena, important in pathology and practice, which must be regarded as affections of sentient nerves, from causes acting in the Nervous System, but in parts

of it distinct from those to which they are naturally referred. These are independent of the feelings which are strictly called Sensations of Emotion, which will be mentioned along with the other effects of emotions on the body.

I. The phenomena which are strictly called Sympathetic Sensations, are of this kind. These are cases where a sensation, distinctly referred to one part of the body, is known to be produced by an impression made on another part. Of these we may make two divisions.

1. The first is where a cause acts somewhere in the course of sentient nerves, or at their origin at the base of the brain or in the spinal cord, and the sensation produced by it is referred to the extremities of a nerve; because the part where it is excited is the same, where the nervous action, necessary to sensation, had formerly been produced by impressions made on those extremities. Such sympathetic sensations are illustrated by the sensations felt in the stump of an amputated limb, and referred to individual parts of the limb that has been removed. Of this kind, are the sensations of a flash of light from an injury of the eyeball or brain; the sensations of suffusiones, of tinnitus aurium, of nausea, of aura epileptica, referred to the eyes, ears, stomach, or limbs, in consequence of peculiar diseases of the brain, no doubt affecting the origins of the nerves; the sensation of pain often referred to a paralytic limb, after an attack of palsy from diseased brain; the sensation of pain or tightness, stretching round the chest or abdomen, from disease or irritation of the spinal cord, as in paraplegia; pains of various parts of the lower limbs from the pressure of aneurisms of the aorta on the spinal cord or lumbar nerves; and the slighter sensations of the same kind seen in hy-

sterical cases, and sometimes best relieved by remedies applied over the origin of the intercostal or lumbar nerves; the sensation of pain, often referred distinctly to the neck, back, or different limbs, in the course of hydrocephalus.

2. There are many instances of pains distinctly referred to one part of the body, but which are known, from experience, to proceed from irritation or disease of another part. These *sympathetic*, or, as they have been lately called, *radiating* sensations may, in several cases, be ascribed to connexions of the sentient nerves of the parts (especially when the part really injured is internal, and that to which the feeling is referred is external, and both have their sentient nerves from the same larger branches), and may so be brought under the same head as the last; but we cannot, as yet, refer all such cases to this principle.

Of this kind are, the pain of the shoulder from disease of the liver or diaphragm; pain of the urethra and glans from disease or irritation of the bladder; pain of the testis and thigh from irritation of the kidney; pain of the side of the neck and head, and of the left arm, from disease of the heart; pain of the back from disease or irritation of the uterus; pain (and spasms) of the legs from irritation of the intestines, as in cholera; pain of the knee from disease of the hip-joint in the morbus coxarius; pain of the forehead from irritation at the stomach; pain of the cheek or temple from irritation of a tooth; itching of the nostrils from irritations in the bowels; the uneasy feeling referred to the teeth from harsh grating sounds; uneasy sensations in the nose from bright light affecting the eyes; and various other less frequent sensations, in constitutions of unusual sensibility, which are distinctly referred to one part of the body, but traced to irritation of other parts.

In both these cases it is often observed, that there is

not only a mistaken judgment, as to the seat of the cause exciting the sensation, but some physical effect (*e. g.* inflammation in a greater or less degree), follows in the part to which the sensation is referred, which implies that some change is really propagated downwards, along the sentient nerves of these parts to their extremities, influences the capillary circulation in their neighbourhood.

II. Another set of facts which must be referred to the head of sensations proceeding from internal causes, but exactly resembling those excited by impressions from without, consists of cases of Spectral appearances, or sounds, differing from the sympathetic sensations now considered, in being exact representations of certain definite and complex impressions on the higher senses ; and differing from mere recollections, or fancied scenes, in being equally vivid and distinct, and equally beyond the control of any voluntary mental effort, as the sensations excited by real impressions from without.

The most common case of such spectral appearances, is in persons under the influence, or recently recovered from the influence, of opium or of strong liquors ; but they occur occasionally in persons of what is usually called Nervous temperament, independently of any such cause.*

Cases recorded by Dr Bostock (System of Physiology, vol. iii. p. 204), and others prove, that these spectral appearances are not merely the repetition of past sensations, but, in some instances, differ from any thing that has ever been presented to the senses ; in which case, their excitation implies the exercise of that mental power which is strictly called Imagination.

* See the works of Alderson, Ferriar, and Hibbert, on Apparitions, Brewster's Natural Magic, and Abercrombie on the Intellectual Powers.

It was formerly stated, that the sensations, and other mental feelings, so easily reproduced during darkness and silence, after unusual muscular exertions, or unusually strong impressions on the senses,—as well as other facts, pretty clearly indicate, that the nervous system is not passive during the performance of its different functions, but undergoes various, although imperceptible, changes corresponding to them all. It is probable that a slight degree of the same changes, in the sensitive nerves, which accompanied the original excitation of all sensations, may accompany every act of recollection of these ; and that similar changes may attend acts of imagination, by which imitations of objects of sense are created in the mind (in which operations we shall find that the mind acts for the most part involuntarily) ; and if, on particular occasions, these physical changes are in any way rendered stronger and more enduring than usual, it is only in conformity with principles already stated, and to be afterwards more fully explained, that they should impress the mind, for the time, with the idea of the external and independent existence of the causes exciting them.

Various cases have been recorded, at different times, in which it was thought that, during a singular excited state of the nervous system (called Somnambulism or Reverie), slight impressions, on the sense of touch only, were followed by sensations which gave correct information of kinds coming within the province of the special senses. We cannot conceive that the conditions which appear to be essential to the exercise of these senses, can be imitated in this way ; and the moral evidence, attending such alleged cases of transference of the sensual powers from one part to another, is very liable to suspicion ; yet there is a striking similarity in the different cases of this kind, recorded by different observers, unknown to each other,

which demands farther inquiries, before we can think ourselves entitled to reject such observations as mere fallacies.*

If, indeed, all the information which we obtain by the senses, were either contained in the sensations themselves, or logically deducible from the intimations of sense, we should say with confidence of such cases that they must necessarily involve some unperceived fallacy. But we must necessarily admit the principle of Intuition, as part of the cause of all the information derived from the senses; and once admitting it, we cannot assign a limit, otherwise than by experience, to its operation.

* See Rostan, Art. Magnetisme Animal, in the Dictionnaire de Medecine, Bertrand "Du Magnetisme Animal en France." Isis Revelata, by Mr Colquhoun, and the Report of the Committee of the French Academy of Medicine, contained in that work.

CHAPTER XIV.

OF THE MENTAL FACULTIES.

THE sensations which we feel in consequence of external impressions, are manifestly instrumental in exciting, and are continually mingled with, certain other internal changes, of which we are conscious, and to which we give the general name of Trains or Successions of Thoughts.

The method of inquiry which it is necessary to pursue, in order to acquire satisfactory information as to these operations of our minds, is just the same as that which is followed in the physical sciences; consisting first in the careful observation, and then in the comparison and classification, of individual facts, whereby we acquire the knowledge of general principles, or laws of this department of nature. But as attention to the changes which take place in our minds requires a peculiar and often painful effort, to which few men have carefully accustomed themselves, and as the words employed to denote the transitory thoughts or states of mind of which we are conscious, are necessarily analogical, and very easily misapprehended, there has been a want of precision in the conduct of most inquiries on this subject, as compared with those made into the laws of the material world; and the results have been less satisfactory.

In order to avoid such errors, all that seems necessary is, *first*, To recognise the necessity of patient attention to, and *reflection* upon, the different thoughts that pass through our own minds, as the only foundation of accurate knowledge in this department of science; *se-*

condly, To define strictly, and observe carefully, the meaning of all the words employed to denote the changes of which we are conscious ; *thirdly*, To understand distinctly the objects of inquiry into the operations of the mind, and the limits which nature has imposed on the gratification of curiosity on this subject, and which are just similar to those that circumscribe our researches in all other departments of science.

The first observation that may be made on the thoughts of which we are conscious, is, that they are all *transient*, or in a continual state of change, one act or state of mind passing away, and another succeeding. Hence two inquiries naturally present themselves, which have not perhaps been so carefully distinguished as they might have been ; 1. Into the nature or characteristics of the different acts or affections of mind that succeed one another ; and 2. Into the laws which regulate their succession.

I. The exercise of our senses naturally and immediately leads us to form certain General Ideas or notions, the tendency to the formation of which has been called by some metaphysicians, the Power or Faculty of Simple Apprehension ; and in connexion with these, we have a natural disposition to put faith in certain propositions or principles, which have been called by Dr Reid, Principles of Common Sense, and by Mr Stewart, Fundamental Laws of Human Belief ; of which no proof can be given ; which we know, not from Reasoning, nor from Experience, but by Intuition ; and our confidence in which must be stated as an *ultimate fact* in the constitution of our minds. A little attention to the existence, and to the authority, of these laws of belief, will enable us to set aside a great deal of useless controversy, and simplify our account of the mental part of our constitution.

Acquiescence in these principles is, in fact, equally necessary in the prosecution of physical, or even of mathematical science, as of metaphysics; but in the former sciences, they have been always *tacitly admitted*; and only brought into question in the latter, because it is only in the latter that the instruments by which truth is sought, are themselves made subjects of discussion. But as we have no instruments to apply to inquiries into the mind itself, different from those which we employ in the other sciences, we must be content to use them in the same manner, and trust them equally; otherwise we must abandon the labour.

"All reasoning," says Dr Reid, "must be from first principles, and for first principles no other reason can be given than this, that, by the constitution of our nature, we are under the necessity of assenting to them. Such principles are parts of our constitution, no less than the power of thinking. Reason can neither make them nor destroy them, nor can it do any thing without them. A historian or a witness can prove nothing, unless it be taken for granted that the memory and the senses may be trusted. A natural philosopher can prove nothing, unless it be taken for granted, that the course of nature is uniform, or her laws permanent. That my thoughts and sensations must have a subject which I call myself, is not an opinion got by reasoning, but a natural principle. The belief of it, and the very conception of it, are equally parts of our constitution. If we are deceived in it, we are deceived by Him that made us, and there is no remedy."

"Deny the evidence of memory as a ground of certain knowledge," says Mr Stewart, "and you destroy the foundations of mathematical science, as completely as if you were to deny the truth of the axioms of Euclid:"

but no man can give a reason for believing in what he remembers, any more than in what he feels.

Those who do not put faith in *any* such fundamental laws of belief as are here mentioned, are thereby disqualified for scientific inquiries of all kinds, equally as they would be by the loss of the faculty of memory; because it is manifestly absurd for any one, who has determined that he will believe nothing, to engage in the pursuit of knowledge.

But those who admit that there are *some* principles which must be believed, for no other reason than that we cannot help believing them, may reasonably inquire, in regard to any individual principle, which commands the general assent of mankind, whether it is really of this kind, or whether the belief reposed in it can be founded on any fallacy: and the following have been stated as the most distinctive marks of those principles which we are entitled to regard as fundamental laws of human thought.

1. These principles are formed, and in the first instance believed, uniformly by all men, and in all circumstances, and do not appear to be influenced by any accidents, of situation, habits, or previous associations of individuals.

2. They are of such a nature, that they can neither be attacked nor defended, in any other way than by reference to principles, which are not more universal, and have no other foundation, than themselves.

3. Their practical influence is found to extend, even to those who affect to question their authority.*

Judging by these marks, and by carefully attending to the natural, uniform, and irresistible tendency of our

* See Stewart's Elements of the Philosophy of the Human Mind, vol. ii. ch. i. art. 2 and 3.

own minds, we believe that the following principles, so formed, may be regarded as belonging to the class of fundamental laws of belief.

1. The belief in the existence of the sensations and thoughts which pass through our minds, and in our own existence, as sentient and thinking beings,—or the faith we repose in the Evidence of Consciousness.

2. The belief in what we remember to have felt or thought, or in the Evidence of Memory, and in our own Identity during the whole time to which our memory extends, which implies the formation of the general idea of Time.

3. The belief, already mentioned, in the external and independent existence of the causes of our sensations, or in the Evidence of Sense, which involves the formation of the general idea of Space.*

* The sceptical argument against this universal belief, when reduced to its simplest terms, appears to be this, That we know nothing of any existences external to our own minds, except by means of those feelings which we call Sensations, and therefore that "the material world, if such there be, must be the express image of our sensations;" but that a sensation is a mental change only, and it is absurd to suppose that any thing can resemble a sensation, except another sensation in the same or another mind.

The answer given by Dr Reid and others to this argument is, That although it is by means of sensations that we acquire our knowledge of external things and their properties, yet, in point of fact, the notions which our minds are so constituted as uniformly and necessarily to form of these (at least in the case of the primary and most essential qualities of bodies already noticed, p. 289) have *no resemblance whatever* to the sensations, through the intervention of which they are formed; that the material world, as made known to us through our senses, is *not the express image of our sensations*, nor does it resemble them in any particular; and therefore, that although our notions of its nature, and belief in its external existence, cannot be explained, and may be said to involve a *mystery*, as every ultimate

4. The belief in the existence of an Efficient Cause, for the changes that we see take place around us, which implies the formation of the general idea of Power.

Here it is to be observed, that our senses never inform us of any events in nature as being causes of other events, in any other way than by shewing that they are immediate and invariable antecedents of these. It is only by experience of the consequences which follow any change, that we learn what consequences to anticipate, when we see the same change again.

But although this be the case, most philosophers have thought, that the mere observation of changes in the world around us naturally suggests to the mind, not only the facts of antecedence and consequence, but farther, a general notion or idea, which we express by the term Power; and the notion thus expressed, being truly an attribute of Mind, is considered as the first step in Natural Theology.*

fact, whether in physics or metaphysics, does, yet they involve no *absurdity*. The essential point of this answer is not correctly stated by Dr Brown in his criticism on it.

* That this is a fact in the natural history of the mind is denied by others, and especially by Dr Brown, who argues that no farther idea is annexed to the term Power, than merely "invariable antecedence," and that the mere observation of the changes of physical events would never suggest the notion of any attribute of mind, that being only suggested, according to him, by the observation of *contrivance*, or adaptation of means to ends. (Lecture 7.)

But that a general notion, distinct from mere uniformity of sequence, and most correctly expressed by the term Power, does suggest itself to the mind, on the mere observation of physical changes, appears not only to be sufficiently proved by considerations stated by Mr Stewart (Outlines of Moral Philosophy, § 257), but to be distinctly admitted by Dr Brown himself, in other parts of his Lectures. Thus, in speculating on what would have been the effect, "if the generations of mankind could have existed in a world of dark-

5. The belief in the stability of the Order of Nature, which is necessary to enable us to apply the experience of the past to the conduct of our lives, or to the knowledge of natural phenomena acquired by one person, to the instruction of others. This belief is judged not to be the result of experience, because it may be observed to operate the most strongly in those whose experience is most scanty, and in relation to subjects which are perfectly new to them.* Indeed several philosophers teach, that our belief in the independent existence of external things, being founded on a *repetition* of sensations, is resolvable into this principle of our nature.

6. Our belief in our own Free Will, involving the general idea of Voluntary Power, in like manner attends a part of those mental changes, which the exercise of sensation excites.

In regard to this, just as in regard to the other principles now stated, it is a fair question, whether there is any reason for thinking that the feeling of voluntary power, which undoubtedly attends certain acts of the mind, can be fallacious. But if no irresistible reason be stated *against* the belief, it is unreasonable and unphilosophical for us to ask, because it is impossible for us to

ness, and then the sun had arisen suddenly on the earth," he says it would have been sufficient to shew, "that there is a Power *which can create*." "The sudden appearance of the sun would have indicated Power of some sort;" and again, "After a few successions of days and nights, its regularity would *add* to the previous conception of Power some conception of corresponding *order*; (Lecture 92.) This passage, and others to the same purpose, sufficiently demonstrate that the conception of *sudden and striking change* was sufficient to introduce the idea of Power, exactly as commonly understood, even to a mind that had denied the possibility of its introduction in that way.

* See Stewart's Elements, vol. ii. chap. i. sect. 3.

obtain, any other reason *for* the belief, than the fact, that in performing certain of the mental acts, of which we are conscious, we are naturally and uniformly impressed with the conviction, that we may do so or not as we please. If no clear proof be given, that this conviction is erroneous, and that the general notion of free will it involves is a fallacy, all that we have to do is to state, in the course of our account of the different mental phenomena, what the circumstances are, in which it uniformly and spontaneously arises in our mind.

What has already been said of Sensation, and of these different acts of Thought, which naturally and inevitably succeed sensation in every individual of sound mind, is sufficient to shew that the only *foundation of much of our belief*, and the only *source of much of our knowledge*, is to be found in the *constitution of our own minds*. Not only are the notions that we form of the qualities of external things, which affect our senses, totally different from our sensations themselves, but certain general ideas, which inevitably arise in our minds, in consequence of the exercise of our senses, are at once perceived, when the attention is fairly fixed on them, to have an extent of application far beyond what the senses themselves can ever reach. The simple notion of our own existence, which is sufficiently suggested to our minds by the occurrence of any single sensation, instantly extends to the whole period of which our memory gives us any information. The notion of Power, or Causation, which may be suggested by the observation of a single striking change in the world around us, is immediately judged to be applicable to all changes without exception. The notion of Time is no sooner formed, than it swells in the human mind to Eternity, as surely as the notions of Space and of Number to Infinity.

Even from these simple instances, it appears, how necessary an addition was made to the scholastic maxim, "Nihil in intellectu quod non fuerit prius in sensu," by the words "Nisi intellectus ipse;"* and how extended a meaning we must annex to the word Reflection, if we assent to the doctrine of Locke, that all our knowledge is derived from Sensation and Reflection. Although "sensible objects may be the destined medium to awaken the dormant energies of the understanding, yet are these energies themselves no more contained in sense, than the explosion of a cannon in the spark that gave it fire."

It is next to be observed, that many of the mental acts, which are felt as constituting our trains of thought, consist in a certain renewal, or what we call Recollection of past Sensations. The act or state of mind which constitutes such a recollection is felt as much slighter, and much more transient, than that which followed the impression formerly made on some one of the senses, but is precisely similar to it. To this act of mind the term Conception is properly restricted.

Farther, this act of mind, transient as it is, always carries along with it a conviction, that a precisely similar state formerly existed in consequence of an impression on the senses; and to this *conviction of past existence*, attending the consciousness of the present existence, of this or any other mental act, we properly refer when we use the term Recollection, or Memory.

The act of mind, distinguished by these last terms, is so very frequent and important, that it accompanies or immediately succeeds almost all others, and appears, on consideration, to be essential to the formation of our sim-

* Leibnitz.

plest notions of the qualities of objects, and to the other mental acts which immediately result from sensation.

The Conceptions, or renewed images of past sensations, present themselves to the mind in succession, and mingled with other thoughts, quite independently of any effort of the will. And on reflection on such involuntary successions of images in the mind,—particularly on such as from any cause impress themselves more strongly, and remain longer, than usual,—it is thought by several metaphysicians, that there is a natural tendency of the mind to conceive them as representing external and independent existences, in like manner as sensations do. This tendency is instantly checked, and prevented from leading to a false judgment of the mind, by two circumstances: —1. Although each conception is involuntarily presented to the mind, yet we are conscious of a voluntary power either of retaining it, and fixing our attention on it, or of letting it pass off, which naturally leads us to believe, that it has no existence independent of the mind that is conscious of it :—2. The conceptions are continually intermingled with real sensations, dependent on impressions from without, which convey to us a notion, known to be correct, of external and independent existence ; and which we feel to be more permanent than, and different from, the conceptions ; and often to be incompatible with the external existence of any causes corresponding to these.

That there is a natural tendency to believe in the independent existence of the causes of our conceptions, as well as of our sensations, appears probable from the state of our minds, when many vivid recollections of past sensations, or fancied images closely resembling such recollections, with little interruption either from present sensations or voluntary efforts, are called up by an interesting narrative read or heard ; and still more by the state

of mind during Sleep, when both the checks, stated above, to the belief reposed in them, are withdrawn (sensations being little felt, and voluntary efforts suspended); and when the same belief attends conceptions, as attends sensations and perceptions in our waking hours.*

These statements are important as illustrating the formation of delusions in Delirium and Mania, when, in consequence of conceptions (and other acts of thought to be afterwards mentioned) being more vivid, and more lasting than usual, and absorbing the attention more completely, their causes are believed to have a separate and independent existence, just as those of sensations are in the healthy state.

The power or disposition of the mind to form, at any future period, the conception of, *i. e.* to remember, any sensation, or indeed any former act of thought, depends very much on the circumstances in which the original impression is made, and especially on the state of the nervous system at the time: For sensations felt in youth are longer remembered than those which are first felt in advanced life; and impressions made on the senses during intoxication, or during sleep (provided they do not interrupt sleep), or during certain diseased states of the nervous system, although they cause sensation, and even some of the usual effects of sensation, both mental and bodily, are yet very imperfectly, or not at all remembered.

Next, a very important part of the trains of thought, which the exercise of the senses excites in the mind (and which implies indeed an exercise of the different faculties already considered), consists of acts of *Abstraction*, by which we separate from the complex sensation or conception, corresponding to any individual object, certain of

* See Stewart's Elements, vol. i. chap. iii.

the qualities which that object possesses, and make them distinct objects of attention; thereby forming to ourselves general or abstract ideas or notions, in addition to those, the formation of which has been already described, and enabling ourselves to form classes or genera of objects. Thus when we compare any two bodies, and observe them to be both black or both white,—compare two animals, and observe them to be both quadrupeds,—two flowers, and observe them to be both fragrant, we begin to exercise this faculty of abstraction, which enable us to occupy ourselves with the *general relations of things*, and to classify and methodize our knowledge. The nature of this mental operation is perhaps best expressed by the term used by Dr Brown, the Suggestion of Relations.

It is obvious (on a little reflection), that the general qualities of objects, expressed by such terms as white, black, tall, short, round, square, &c. and that the general classes of objects, as plant, animal, horse, dog, formed by attention to their respective qualities, and relations to each other,—have no real external existence, but belong only to the individuals referred to these classes, or invested with those qualities; and it has even been disputed whether any definite notions of these abstract qualities, or of the classes distinguished by means of them, are ever formed in the mind,—some philosophers thinking that it is only by means of the *words* employed to denote such abstract ideas, that we are enabled to make them objects of thought. This is the substance of the metaphysical dispute between Realists, Nominalists, and Conceptualists. But it appears beyond doubt, that the operation of the mind, by which the relations of things are perceived, and by help of which the objects of our knowledge are arranged into classes, is not only independent

of language, but is a necessary preliminary to the use of all abstract or general terms.*

It is important to observe how generally, by means of this faculty of mind, and of the general notions already mentioned as immediately succeeding sensation, our thoughts are elevated above individual objects of sense, and occupied about what are called abstract ideas, or classes of objects; and this is well illustrated by the nature of language;—for there is only one class of words (substantive nouns), and only a part of these, which express what is individual; all others denoting either classes of objects, comprising many individuals; or qualities, or events, common to, or contingent upon, many. This, accordingly, is the faculty, the more perfect possession of which appears to furnish the most essential and fundamental distinction between the human intellect and that of the lower animals.

Again, in reflecting on such acts of thought, a farther

* See Brown's Lectures; Lecture 46 and 47. The following sentences contain a summary of his doctrine on this subject, which is substantially the same as that of various other authors:—"We perceive two or more objects. This is one state of the mind. We are struck with the feeling of their resemblance in certain respects. This is a second state of the mind. We then, thirdly, give a name to these circumstances of felt resemblance,—a name which is of course applied afterwards only where this relation of similarity is felt. It is unquestionably not the name that produces the feeling of resemblance, but the feeling of resemblance which leads to the invention or application of the name; for it would be equally just and philosophical to say, that it is the name of the individual John or William which gives existence to the individual John or William, and that he was nobody, or nothing, till the name was given,—as to say that the name Man, which includes both John and William, is that which constitutes our notion of their resemblance; and that but for the name, we could not have conceived them to have any common properties."

distinction presents itself; the mind not only forms general notions of the qualities or relations of objects, but likewise perceives and decides on the relations of different objects to one another, or to these abstract ideas of its own formation. Thus the separate conceptions of two quadrupeds not only suggest to us the general idea of resemblance, and the general class of quadrupeds, but likewise fix the relation which each of these individuals bears to those general notions; and this is what is strictly meant by the mental faculty or power of Judgment. A succession of individual acts of this kind takes place when we apply our experience of individual sensations to the formation of classes of objects, and to the determination of laws of nature; and again, when we deduce certain conclusions, either from ascertained laws of nature, as in physics, or from arbitrary definitions of our own, as in mathematics.

In exercising this faculty of judgment, we are guided, or our judgments are determined, partly by the knowledge we have acquired, or the definitions we have laid down, of the subjects on which our thoughts are occupied, and partly by the intuitive principles or laws of belief already mentioned.

All the acts of mind hitherto mentioned are said to be simply Intellectual; they cannot be strictly called either pleasant or painful; and they prompt to no acts of volition: but other feelings form part, even of our simplest trains of thought, which are at once felt to belong to a different class. Emotions of Pleasure, Pain, Surprise, Fear, Resentment, Curiosity, &c.—feelings which neither admit of nor require definition,—immediately succeed both the excitation of present, and the recollection of past sensations; constitute a great source of enjoyment,

and form a part of what are called the Active and Moral Powers or Dispositions of our nature.

The different acts of mind now considered,—the Apprehension or formation in the mind of certain general notions, the Conception and Remembrance of past sensations, the Abstraction of certain of the qualities of objects from others, so as to form additional general notions, and, by them, classes of individuals; the Judgments of the relations of objects to one another, and to these general notions; and the simple Emotions, pleasing or painful, which several of these operations excite; are the simplest elements that compose those varied trains of thought, which the exercise of our senses excites.

And before going farther, we can pronounce, with confidence, on the inaccuracy of the theory of several French philosophers and physiologists, who resolve all acts of Thought into Sensation,—a theory which, in fact, amounts to nothing more than an extension of the term Sensation to what, in our language, is expressed by the more general term Consciousness. If we were to adopt that extension, we should not only involve ourselves in misapprehensions, but should be obliged afterwards to subdivide the sensations, so as to make them correspond to what we now call the different mental faculties.*

* "I perceive a hare," says Dr Brown, "and I perceive a sheep: each of these separate states of my mind is a sensation. I cannot attend to them long without comparing them, and perceiving those circumstances of agreement, which lead me to apply to both the term Quadruped. The one state of mind is a consequence of the other state of mind. But this is far from proving the comparison itself, as a subsequent state or phenomenon of mind, to be the *same mental state* as the mere perception of the two animals which preceded it. If the evidence of our consciousness is to be trusted, it is very different; and on what other evidence can the assertion of their

But when our minds are employed for their destined use, either for the acquisition of knowledge, the pursuit of pleasure, or the attainment of any practical purposes, it is plain, not only that these different mental acts must take place, but that they must succeed one another in a determinate order, and tend to a definite object; and accordingly, before we can consider the two noblest and most characteristic, but also most complex, of the mental powers, those of Imagination and of Reasoning, by which the conduct of our lives is chiefly directed, we must take notice of the laws which appear to regulate the successions of thoughts in our minds.

II. In this respect there is observed a much greater difference among individuals, or in the same individuals at different times, than in regard to the nature of the mental acts. There are first, certain laws as to the succession of thoughts, which are imposed by nature on the minds of all; and secondly, there is a certain power which we feel that we can exert voluntarily on our own minds.

1. The rapidity with which all the component parts of the train of thought pass through the mind, is very various in different persons; different in youth and age; perhaps generally different in women and men. And there is a still more striking difference between individuals, as to the length of time during which certain peculiar objects of thought dwell on their minds, and the degree of attention they excite. Thus some persons are

sameness is founded?"—"It is not as being susceptible of mere sensation, but as being susceptible of *more than mere sensation*, that the mind is able to *compare* its sensations with one another." (Lect. 33.) See also Stewart's Philosophical Essays, Essay i. ch. 3 and 4, and Essay iii.

strongly impressed by differences of colour, some of forms, some of countenances; the minds of some dwell habitually on certain abstractions, such as numbers, or mathematical figures; those of others on certain of the properties of external objects; those of others on the words by which thoughts are expressed, &c. The memory of all subjects of thought depends very much on the length of time that they have occupied the mind; and therefore the subsequent recollections, and the usual reflections, of different minds, will necessarily depend very much on the peculiarities of this disposition of Involuntary Attention. The striking differences of individuals, in this respect, are well illustrated in the writings of Gall and Spurzheim, and their followers.

2. In the same person, at different times, there is also great variety as to the rapidity with which different thoughts succeed one another, and as to the intensity of mental attention which is fixed upon them; sometimes from physical and sometimes from moral causes. The effect of any cause accelerating the circulation in the brain, in a degree consistent with health, is to increase, for a time, the rapidity and the energy of the mental acts; and the same is often remarkably seen in the stage of greatest vascular excitement, in febrile and inflammatory diseases. The effect of every emotion or moral feeling, which blends itself with any mental act, is to modify the rapidity of the train of thought at the time; sometimes to quicken it, as in the case of joy; sometimes more remarkably to retard it, and keep the same image or idea long before the mind, as in sorrow; but always to give additional intensity to the involuntary disposition of the mind, to attend to any such act; as is often shewn, by the long and vivid subsequent recollection of such thoughts, and by the slight degree of attention which any object of

sense presented during the continuance of the emotion receives, and the very short period to which the power of recollecting it extends.

3. It would appear that the mind is truly "incapable of attending at one and the same instant to objects to which it can attend separately;" although the length of time during which a single object of thought remains before the mind is often so inconceivably short, as to deceive us into the belief of its actual coexistence with others.* At least, when any mental faculty is strongly excited, or the attention strongly fixed on one mental act, any other mental act is imperfectly performed, is hardly an object of attention, and fails of its usual effects. Mental occupations of intense interest, or violent muscular exertion, greatly diminish the intensity and the effect of sensations excited by impressions on the senses. On the other hand, any very intense and uneasy sensation so engrosses the mind, as to disqualify it for carrying on any continuous train of thought, or exciting any definite succession of muscular efforts. And when two distinct impressions are made about the same time on the senses, the stronger sensation overpowers or obscures the weaker.

This principle is of great importance in the pathology and treatment of disordered states of the mind. But in the healthy state, and when none of the mental acts take place with unusual force, there is frequently a *virtual* coexistence of feelings or thoughts, which, when strictly analyzed, appear widely different from each other.

4. Much attention has been paid to the different bonds of union that exist among our thoughts, or the laws of association according to which they succeed each other. When we reflect on the very various thoughts which pass through the mind within a short time, we are sometimes

* See Stewart's Elements, vol. i. ch. 2.

quite at a loss to detect any principle to which we can ascribe their succession; nor is it certain that any such connecting principle does always exist; but in general we may observe, that one suggests another, either by reason of *previous Association* in the mind, of *Resemblance*, or of *Contrast* in the objects themselves.*

When two events which immediately succeeded one another,—when a cause and its effect,—when the different parts of a complex scene, or the different countenances of an assembly of persons,—when the successive steps of a demonstration, or heads of an argument, already gone through,—present themselves to the mind in succession, it is obvious that they have been suggested by the principle of previous association. And, in proportion as that previous association has been more recent, as it has been more frequent, as it has been less disturbed by other concurrent circumstances, as the thoughts constituting it have been longer and more strongly impressed on the attention of the individual, either from his natural disposition, or from emotions formerly attending it, —the same succession of thoughts will be more certainly and more perfectly reproduced.

The associating principle of Resemblance, again, often brings together in the mind, not only objects of sense, which have obvious and striking similarities, but thoughts

* On this subject, Dr Brown makes a just and acute observation. "All suggestions, I conceive, if our analysis be sufficiently minute, may be found to depend on *prior coexistence*, or immediate proximity. For this very nice reduction, however, we must take in the influence of *emotions* and other feelings; as when an object suggests an analogous object, by *the influence of an emotion or sentiment*, which each separately may have produced before, and which is therefore common to both. But it is very convenient, in illustration of the principle, to avail ourselves of the mere striking subdivisions, in which the particular instances of proximity may be arranged."—Lect. 35.

and feelings which resemble each other chiefly in giving rise to the same emotions ; as when any object of interest suggests those slighter and more fanciful analogies, which may be traced among the component parts of the trains of thought to which the epithets of Sublime and Beautiful are appropriated.

Again, in other cases, the resemblances which serve to associate thoughts with each other are in the words which denote them, not in the objects of thought themselves, as is shewn by the fantastic assemblages of thoughts often brought together by rhymes, puns, or alliterations.

Some of the greatest intellectual differences that exist among individuals, turn on the natural tendency of the mind to these associations or successions of thoughts. In some minds the chief associating principle is merely previous association ; and if it be strong, such men are well fitted for practical exertions, varying according as their involuntary attention has been more frequently and longer bestowed on one class of thoughts or another ; but they are not fitted for works of genius. In other minds the chief associating principle is resemblance ; and according to the kind of resemblance or analogy, which they are most apt to observe, and of emotions connected with them, in which they are most apt to indulge, they are fitted for various works of art or of fancy.

It is according to the strength and endurance of more or fewer of these principles of association, that individuals differ in what is commonly called the fidelity and retentiveness of Memory ; and it is by the failure of more or fewer of them, that those diseased states called general or partial loss of memory are chiefly characterized.*

* It may seem a needless multiplication of scientific terms to speak of the images of past sensations being retained by Memory, suggested by the Association of Ideas, and called up by Conception ; and Dr

5. All this applies to the causes which influence, or laws which regulate, the train of thought in the mind, independently of any influence of the Will. The Voluntary power which we may fairly affirm that we are conscious of possessing over the succession of our thoughts, is in all cases *indirect;* because it is plain that to make effort to call up any particular thought, necessarily implies that it already exists in the mind; but it is not the less real or important. " It consists in singling out any one thought that has presented itself, detaining it at pleasure, and making it a particular object of attention; whereby we not only stop the succession which would otherwise take place, but frequently, by bringing into view less obvious relations among our ideas, direct the current of our thoughts into a new channel."* And if this be done repeatedly, and habitually, in regard to the exercise of our minds on any particular subjects,—so as

Brown thought he had simplified the subject considerably by ranking all these powers under one head as Simple Suggestion. But perhaps the generalization is rather verbal than real. When the sight of any scene in nature recalls another which it resembles, it is true that the mind does no more than pass from one state, which the impression made on the eye has excited, into another state which is the conception of the scene formerly before the senses; but it is equally true, that in this mental change, three distinct principles are illustrated; *first,* the power of the mind to represent again to itself an impression formerly made on it through the senses; *secondly,* its power to retain that impression latent, for a great length of time, and recognise it, when again presented, as having been formerly an object of its attention; and *thirdly,* the efficacy of the law of association by resemblance, to which the recollection, at that moment, is to be ascribed. These are all general facts, as to our mental constitution, which connect themselves with others, and demand separate consideration, and hence the propriety of using three different words to denote them.

* Stewart.

to strengthen and rivet particular successions of these by the principle of previous association,—we ultimately acquire, indirectly, so great a voluntary power over our thoughts, that it requires a considerable exertion of attention to observe, that the laws of association which enable us to recall any piece of knowledge for which we have occasion, are in reality fixed beyond our own direct control by the constitution of our nature.

Our indirect voluntary power over our thoughts is often added by our more direct voluntary power over various muscles, whereby we may either command, or prevent, the excitation of sensations, calculated either to confirm, or to break through, those lines of association which we may wish to preserve.

When the various thoughts which pass through the mind are habitually intermingled with Sensations which occupy a certain degree of attention, and are themselves either pleasing, or painful, or calculated to excite any peculiar emotions, both the rapidity of the train of thought, and the kind of mental feelings or operations on which the mind habitually dwells, are very apt to be materially modified; as we observe when we attend to the peculiarities of character of persons who are habitually asthmatic; still more of those habitually dyspeptic; and to the striking differences of the character of the inhabitants of warm and cold climates; of mountaineers and the inhabitants of plains; or of persons habituated to solitude and to society.

When the train of thoughts in the mind is either accelerated or retarded, and particular acts of thought rendered more vivid and engrossing, by strong emotions accompanying them, the indirect voluntary power is proportionally diminished; and this is still more the case when certain of the thoughts acquire an unnatural energy from disease.

The principal varieties of character in individuals, the changes which the mind undergoes in the progress of life, and those to which it is liable in disease, are most easily understood, when they are considered as chiefly depending on alterations of the laws which regulate the duration of thoughts before the mind, and their succession in the mind; rather than of the faculties or powers, of which the individual acts of thought, when analyzed, appear to be composed.

III. It has been already said, that the highest and most characteristic faculties of the mind are those of Imagination and of Reasoning; by the first of which we understand the power whereby the mind voluntarily combines various of its conceptions and abstractions, and forms a visionary creation of its own, differing from any thing that has been presented to the senses; and by the second that whereby the mind voluntarily connects together successive acts of Judgment on the relations of things; and so adapts premises to conclusions in matters of speculation, and adapts means to ends in practice.

It is obvious that the exercise of both these faculties implies (or that they consist in) not only the performance of the simpler acts of understanding already considered, but likewise a certain determinate succession of such acts, regulated in the manner above stated by the will; and that these complex mental acts may be altered or suspended by any alteration of the laws, by which the succession of thoughts in the mind is determined; and it is in this way, accordingly, that they are chiefly altered or perverted in disease.

In the conduct of life, it is most generally by an exercise, more or less complex, and partly voluntary, of the Faculty of Imagination, that we propose to ourselves

objects of pursuit; and then, by an exertion more or less sustained, of the Faculty of Reasoning, that we adapt means to the attainment of these ends.

As the more elementary acts of Thought,—Sensations, Conceptions, and the perception of the simpler relations of things,—are attended with emotions, pleasing and painful, and sometimes with instinctive propensities, so the more complex acts now in question are attended with what are more strictly called *Desires;* which are, in general, anticipations of enjoyment, of one kind or another, consequent on the prospects, more or less fanciful, of effects to be obtained by our exertions, and accompanying the complex mental acts, by which these prospects are to be realized. Thus, the Desire of Pleasure, the Desire of Power, the Desire of Knowledge, the Desire of Esteem, the Desire of Praise, the Desire of Social Intercourse,—attend the acts of Imagination and of Reasoning on the common affairs of life, and bear the same relation to them as the Instinctive propensities do to the Sensations by which they are excited, *i. e.* they constitute the chief Motives to our actions.

Farther, in like manner as the perception of the qualities of material things, and the simpler relations of objects of thought, naturally excite in our minds certain simple ideas, and compel our assent to certain intuitive truths, so the observation or anticipation of certain actions and their effects, naturally excite in our minds the notions of Right or Wrong, Justice and Injustice, which may in like manner be held to be ultimate facts in our constitution; and which, when combined with the consciousness of a certain degree of voluntary power, impose on us the sense of Moral Obligation.

As almost all human actions tend to procure some kind of enjoyment or advantage for the agents, some authors

have thought that the simplest and most satisfactory view of this subject is, to suppose that all motives to action resolve themselves into the desire of pleasure; and much has been said to prove, that as the highest and most enduring pleasure is derived from the exercise of virtue, there is nothing adverse to morality in this view of human motives and conduct. But the considerations urged on this point by Mr Stewart, seem quite sufficient to prove that this is an excessive simplification; that we have a sense of Duty, not resolvable into a regard for our own happiness, and which ought to be, and often is, a rule of human conduct.*

* These considerations are,

"1. There are in all languages, words equivalent to Duty and Interest, which men have constantly distinguished in their signification. They often coincide in their application, but convey very different ideas.

"2. The Emotions excited by the contemplation of what is right or wrong in conduct, are different, both in kind and degree, from those which are produced by a calm regard to, or careless disregard of, our own happiness. This is particularly remarkable in the emotions excited by the conduct of others, for few men are perfectly fair judges of their own actions.

"3. Although philosophers have shewn that a sense of duty, and an *enlightened* regard for our own happiness, do, in most instances, give the same direction to our conduct, yet this is a truth by no means obvious to the common sense of mankind, but deduced from a very extensive view of human affairs, and of the remote consequences of human actions. Consequently, the great lessons of morality, which are obvious to the capacity of all mankind, cannot have been suggested to them merely by a regard to their own interests.

"4. The same conclusion is very strongly confirmed by the very early period of life at which judgments on the moral character of actions make their appearance,—long before children can form such a general notion of happiness as can demonstrate the coincidence of duty with self-love, and indeed in the very infancy of reason."—Outlines of Moral Philosophy, § 172.

We must consider, therefore, the general notions of Right and Wrong, which present themselves on a view of the effects, or probable effects, of human actions, as an ultimate fact in our mental constitution, or a primary element of human reason, equally as the notions of Power, of Intuitive Truth, &c. ; and which imposes on all persons of sound mind a sense of moral obligation, although many circumstances constantly tend, either to weaken its influence on our conduct, or to mislead us in its application.

This slight sketch of the strictly mental phenomena may serve to illustrate the different sets of facts which require consideration under this head,—first, the formation of certain general notions and principles consequent on the exercise of our senses,—next, the recollection of past sensations,—then the perceptions of the relations of things and formation of farther general or abstract notions : these thoughts are continually mingled, not only with our sensations, and with the recollections of similar states of the mind in time past, but also with emotions, pleasing or painful ; they succeed each other according to certain tolerably definite laws, but are, to a certain degree, regulated by our own will ; and under this guidance, they are so combined and directed as to excite desires, and call up moral feelings, and so furnish motives for action ; and determine the kinds of actions, by which the objects thus set before us may be attained.

We can only go a certain length in determining the parts of the larger masses of the Nervous System contained within the cranium, which furnish the essential conditions to the mental operations now considered ; but the

following facts on this subject appear to be well ascertained.

1. The parts of the nervous system which attain their highest development in the human species, and may, from that circumstance, be supposed to be especially connected with those mental operations in which the pre-eminence of the human species consists, are, the Convolutions of the Brain and Cerebellum, the Corpus Callosum, Corpora Striata, Thalami, and Tuber Annulare. Those which are least developed in the human species, but are proportioned to each other in the different classes of vertebrated animals, and may therefore be presumed to be chiefly connected with sensations and voluntary motion, and to have less connexion with any strictly intellectual acts, are the Spinal Cord, Corpora Quadrigemina (called Optic Lobes in many of the lower animals), and Vermiform Processes of the Cerebellum. The Fornix and Pes Hippocampi attain their highest development in some of the mammalia, but not in man.*

2. Although we commonly give the name of Instinct to all the mental operations of which we see indications in the lower animals, yet it is obvious that many of their actions are guided, not merely by the instinctive propensities which are connected with appetites, but by mental operations similar, in some respects, to those of human intellect. In particular, it is obvious, that sensations are distinctly recollected; that emotions (as those of fear and joy) attend them, both when first excited, and when afterwards reproduced; that these mental acts are associated, and called up in successive trains; and even that some of the simpler relations of things are perceived; so that a certain degree of contrivance (implying some exertion of a faculty of reasoning), may be practised; although it

* See Serres, Anat. Comparée du Cerveau.

is plain that their intellect is very little adapted for forming, or dwelling upon, most general or abstract notions.

Now it has been shewn, by the experiments of Flourens, Magendie, and others, on all classes of vertebrated animals, that the indications of such mental operations are not diminished by cutting off the cerebellum, in the animals that survive the operation; but that they are almost entirely suppressed, particularly in birds, by cutting off the cerebral lobes; which appear to correspond to the great mass of the hemispheres and convolutions of the brain, especially in the leading circumstance of the medullary fibres from the spinal cord expanding and terminating in them. An animal thus mutilated may live long, and is capable of the instinctive actions most directly linked with sensations; swallows what is put in its mouth; moves its legs when irritated, and its wings when thrown into the air; and places itself in the posture which is habitual to it when going to sleep; but when not excited by any impression on the senses, appears in a state of stupor; gives no signs of recollection, even of injuries just inflicted on it; and cannot seek its food, nor even avoid obstacles thrown in its way.

The most reasonable conclusion from these facts appears to be that drawn by Cuvier, that animals so mutilated are still susceptible of sensation, but have no recollection even of sensations just felt; and that such of the strictly mental faculties as these animals possess, and particularly Memory, or the Association of thoughts, are dependent chiefly or entirely on this portion of the contents of the cranium; which, accordingly, is the most material part of what is found peculiarly developed in man.*

* See Cuvier's Report to the Institute on the Experiments of Flourens, in the Recherches Physiologiques of this author, and in the Journal de Physiologie, t. ii.

3. Injuries confined to the hemispheres of the brain have also appeared very generally, in the experiments of Flourens, Bouillaud,* and others, to impair the indications of the strictly mental phenomena; but no distinct evidence has been adduced from experiments, of any one class of these phenomena being more affected by injury of one part of the hemispheres of the brain than of another.

Many persons who have given attention to this subject since the first publications of Gall and Spurzheim, have agreed with these authors in thinking, that sufficient evidence of the appropriation of different parts of the contents of the cranium, to different mental acts, may be obtained by comparing the heads of individual persons, whose characters and dispositions are known; and observing such relative proportions of the different parts of the skull to one another, and such prominences or depressions on the skull, as they consider to be sufficient to indicate the comparative size of different portions of the brain and cerebellum in these persons.

The object of this inquiry appears to be quite philosophical, and was accordingly long ago recommended by Lord Bacon.† There is nothing improbable, nor in the smallest degree at variance with the principles formerly stated (p. 194, &c.), as to the essential distinction between Mind and Matter, in the supposition, that as (by the admission of all) the whole Nervous System furnishes the conditions necessary to the manifestation of the whole mental phenomena, in this state of our existence, —so any one portion of the nervous system may furnish the conditions necessary to the manifestation of any one

* Journal de Physiologie, t. x.

† De Augmentis Scientiarum, lib. 4. c. 1.

part of these phenomena. And it is also possible, that the different portions of the brain may be appropriated, as the phrenologists in most instances suppose, to the exercise of the faculties on particular subjects, or particular classes of objects, rather than to such differences among the acts of thought themselves, as have chiefly attracted the attention of metaphysicians.

But when it is considered, *first*, That there must necessarily be great want of precision, both in the physical and metaphysical part of many of the observations made in this way; *secondly*, That sources of fallacy exist in the inference as to the form or size of the brain, from inspection of the skull, particularly in the neighbourhood of the frontal sinuses, and of the cerebellum, which seem sufficient to vitiate some of the conclusions which these authors have regarded as the best established; and, *thirdly*, That observations made in this way, by different competent observers, have given, in different instances, very discordant results;—it may safely be inferred, that very little reliance can be placed on conclusions drawn from such comparisons, unless these are confirmed from other sources. And it does not appear, on examination of the results, either of experiments on the brains of animals, or of pathological observations on the human body, that any conclusions favourable to the phrenological division of the functions of the different parts of the brain, can be deduced from them.

On the whole, the only point ascertained is, the general appropriation of the great mass of the hemispheres of the brain proper, to the acts of thought; which is by no means peculiar to, and does not derive its chief support from, the writings of phrenologists. The very same kinds of alteration of the mental faculties have been often ob-

served, from disease or injury of very different portions of the brain; and again, large and various portions of the hemispheres of the brain have been found, in other cases, manifestly injured, or even destroyed by disease, without perceptible alteration of the mental faculties, almost to the moment of death.* Experiments and pathological observations would seem to indicate, therefore, that the manifestation of these mental phenomena depends, not so much on the mere presence of any particular quantities of the nervous matter of the hemispheres, or the forms which it presents, as on some other conditions in that nervous matter;† and whether these are, in any respect different from the general conditions, formerly stated as necessary to the nervous actions in all parts of the system, is still uncertain.

All this applies only to the vertebrated animals, and even as to them it is certain, that neither the size of the brain, nor the complexity of the convolutions, in the different classes or genera, bears any uniform or fixed relation to the degree of intellect which they possess. In

* See, for example, a case recorded by Dr Abercrombie (Pathology of the Brain and Spinal Cord, Case 89), where the patient appeared in full possession of her faculties, mental and bodily, a few hours before death; and on dissection, nearly the whole of one of the hemispheres was found in a state of complete softening.

† Flourens' conclusions are, "Qu'une portion assez restreinte mais determinée de ces organes (lobes cerebraux) suffit au plein et entier exercice de leurs fonctions;" and again, "Les perceptions, les volitions, toutes les facultés intellectuelles et sensitives, occupent concurrement et conjointment le meme siege dans ces organes."—(Recherches, &c. p. 161 and 212): and the researches, pathological and experimental, of Bouillard and others, do not enable us to modify this conclusion farther than had been previously done by Cuvier, *i. e.* by shewing that it does not apply to the mere susceptibility of sensation, and of the instincts most closely linked to sensations.

those of the articulated animals which are associated in families, such as the Bee and Ant, we observe indications of mental acts, perhaps more closely resembling those of man, than those observed in any of the higher parts of the scale, but unconnected with any organ resembling a brain.

CHAPTER XV.

OF VOLUNTARY AND INSTINCTIVE MOTION.

We have stated what is known of the conditions, under which the human mind is connected with the body, and is informed of, and affected by, impressions made on the body by any foreign substance. We have now to consider more particularly the laws, according to which the body is subjected to the control of the mind; is made to change with the changes, express the feelings, and minister to the wants, of its immaterial inhabitant.

All the mental acts which can be observed to produce, through the intervention of the Nervous System, any decided effect on other organs of the body, may be referred to the heads of Voluntary and Instinctive Efforts (or Volitions and Instincts), Sensations and Emotions; and partial illustrations of the effects of all these mental acts on the body have already been stated. The effect of the volitions and instincts is much more striking than that of any other mental acts, but is also much more limited; being confined to the direct excitation of certain of the muscles of the body, viz. the voluntary muscles,—through certain of their nerves, viz. those formerly described as the motor nerves; while sensations and emotions produce well marked effects, not only on these muscles, but also on the involuntary muscles, and the secretions.

All the movements which we call either voluntary or

instinctive, are essentially characterized by being immediately preceded by the consciousness of a voluntary effort, and likewise attended by a sensation, which gives information of the position and degree of the muscular contraction that is excited. These mental feelings, accompanying such movements, are easily distinguished. In a case of paralysis, or temporary loss of power in a motor nerve, we have the consciousness of effort without the muscular sensation; and in the case of sneezing, or vomiting, from urgent uneasy feelings, we have the latter with hardly any thing of the former.

The contractions which are excited in the voluntary muscles by these mental efforts, acting through the nerves, are much stronger than any that can be produced by direct irritation of the fibres of these muscles, probably because the nervous fibrils penetrate the whole interior of the muscles, and therefore any irritation acting on them reaches the whole of the fibres more completely than one merely applied to their exterior. But the involuntary, or spasmodic contractions of such muscles, which may be excited by physical irritations of the nerves, spinal cord, or medulla oblongata, are stronger than any voluntary contractions.

Many instances, illustrating the great strength of voluntary muscular contraction, under certain circumstances, have been recorded. In the dead body the tendon of a muscle has generally more tenacity than its fibres; but there are many cases of tendons ruptured, and even some of bones broken (as the patella, or even the humerus), by the vital contraction of muscles attached to them. The muscles of the lower jaw of a man have been known to raise a weight of 300 lb., and the extensors of the back of a delicate girl, in opisthotonos, to counter-

balance a weight of 800 lb.* The disproportion between the size of the muscles and the force which they can exert, is still greater in some of the lower animals, especially insects.

It was formerly observed, that the involuntary muscles require intervals of relaxation equally as the voluntary do; but the increasing difficulty of exciting repeated contractions by efforts of which we are conscious, and the uneasy feeling consequent on frequent repetition of muscular sensations, are peculiar to the muscles employed in the function now under our view; mental efforts being wholly ineffectual, and muscular sensations being hardly felt, in the involuntary muscles.

The actions of the voluntary muscles are habitually more irregular, and their contractions are often continued longer, than those of the involuntary are; and it is evident, from the variety of positions which the limbs may retain during sleep, that all these muscles can rest in various states of contraction; which is of great importance, as enabling them to combine in the performance of complex motions. But the amount of contraction of which these muscles are susceptible, is not so great as that which some of the involuntary muscles, such as the bowels, or the bladder, occasionally undergo.

The rapidity with which separate contractions of voluntary muscles may follow each other, both in the human body and the lower animals, is inconceivable. It has been ascertained that some men can pronounce articulately 1500 letters in a minute, which implies 1500 successive contractions of muscular fibres. If we suppose, with Haller, a relaxation, of equal duration as the contraction, to be necessary to make the sounds distinct from one another, each of these contractions must have

* See Haller, Elem. Physiol. tom. iv. p. 481.

taken place in the 50th part of a second; but even if this condition be not necessary, each contraction must have been willed and accomplished in the 25th part of a second; and during this time, or in the intervals of these volitions, the mind must have been carrying on other trains of thought. According to the calculations of Haller, a dog, in running, will sometimes exert distinct volitions for the movement of his legs, 200 times in a second.

It was already observed, that the strictly Instinctive motions of the voluntary muscles, caused by volitions which instantly and inevitably succeed certain sensations, however complicated they may be, are performed correctly from the first. But when we attend to the manner in which the strictly Voluntary motions, prompted by more complex mental processes, are at first performed in the human species and in some other animals, we observe, that it is only by repeated trials, and after frequent failures, that we learn how to move the voluntary muscles, so as to accomplish the objects desired. This process of education evidently depends on two principles, *first*, on the Muscular Sensations, which accompany all the contractions that the will excites, and which are remembered, and are the guide to the repetition of the same action; *secondly*, on the mental law of the Suggestion of Thoughts by previous Association, whereby each of these muscular sensations suggests the volition, which had formerly succeeded it, in the performance of any complex action; so that, after some experience, the different volitions necessary to its performance, become associated in trains, which follow one another without fixing the attention, and cannot afterwards be broken without an energetic effort of the will.

In attending to the acts of our own minds in perform-

ing any voluntary action which has, by frequent repetition, become *habitual*, we become sensible of the power and importance of this mental law of Association.

Farther, by such habitual repetition of movements, the muscular organs concerned in them are gradually augmented and strengthened (see p. 38); and thus a gradual increase is effected in the strength, facility, and precision, with which habitual movements are performed.

These habitual movements are ultimately performed with so little effort, interfere so little with other trains of thought, and the volitions prompting them are so quickly forgotten, that many writers have considered them as becoming, after a time, truly involuntary. But that this doctrine is quite incorrect appears distinctly from two considerations.

1. That the inconceivably short space of time, in which the different volitions necessary for such habitual movements must take place, and the total want of subsequent recollection of them, furnish no evidence against their existence, is proved by the case adduced by Mr Stewart on this point, of the equilibrist who balances himself on a cord, and, at the same time, two or three rods on different parts of his body.* The frequent, rapid, varied, and nicely regulated movements, by which this must be done, cannot possibly have been associated in any one train, as those in any habitual mechanical operation are,—because they must be regulated by accidents which will vary on each repetition of the experiment; yet they are performed in as short a time, and leave as little traces on the recollection, as those concerned in any such habitual movement.

2. Although "in playing a musical instrument, or in many mechanical operations in the arts, the motions are

* Elements, &c. vol. i. chap. ii.

so rapid, that we find it difficult to say that there could have been a distinct voluntary effort for each, yet these motions cease as soon as the will to move is discontinued, and begin again when it is renewed. This case is most obviously distinct from the motion of the heart or other truly involuntary muscles, in which not only the closest observation can detect no sensation, but the most resolute exertion of the will cannot modify the motion." *

We must be careful, therefore, never to confound those motions which are truly voluntary, however easily they may be performed, and however closely they may have "clung together by association," from those which, by reason of the peculiar endowment of the nerves supplying the muscles employed in them, are truly beyond the control of the will. "Eterna lege separatur Voluntatis imperium ab Irritabilitatis provincia." †

Inattention to this distinction led Stahl, Darwin, and other physiologists, to think, that the same law of Association, which explains the formation of habitual trains of successive voluntary motions, would likewise explain the constant successive movements of the auricles and ventricles of the heart, and the peristaltic movements of the bowels, ‡ and was generally applicable to all muscular contractions without exception; whereas it is in reality a law of mental phenomena only, applicable to those muscular contractions which are excited by mental acts, but not to other muscular contractions.

The distinction formerly stated of the Instinctive from the strictly Voluntary motions, is sufficiently illustrated by the complex acts of sucking and deglutition, correctly performed by the new-born infant; and by a comparison

* Rees' Cyclopædia. † Haller.

‡ Darwin's Zoonomia, vol. i. p. 38, 267, &c.

of these movements with the corresponding actions of other young animals, destined to procure their nourishment in other ways ; but it is difficult to determine what other movements, as seen in the human species, are truly instinctive. Probably, however, not only those movements by which the immediate gratification of the appetites is procured, but those likewise by which we avoid certain injuries immediately threatening us, as in winking, withdrawing the hand from the fire, or throwing forward the arms when we fall,—those by which we move the eyeballs so as to turn the axes of both eyes to an object which arrests our attention,—those by which we close the sphincters, on irritation of the rectum or bladder,—are truly instinctive ; by which we mean that these movements are prompted by volitions originally and directly consequent on certain sensations ; and are not prompted, like the strictly voluntary motions, by the more circuitous process above described, in which reasoning, imagination, desire, and experience or association, are successively concerned.

At the same time it is to be observed, that these instinctive motions are always preceded by distinct efforts of the will, and are not therefore the direct effects of mere sensation ; and in many instances, in the lower animals, they procure no enjoyment, but inconvenience and even suffering, to the animals themselves, although necessary to the preservation of the species.*

The phenomena of these instinctive motions are peculiarly important as evidences of Design in the Universe, because they are precisely analogous to the phenomena, from which we all uniformly and habitually infer the existence of intelligent minds in other men ; they lead directly to the same inference as to Intelligence ; and yet

* See Paley's Natural Theology.

we see clearly, and even feel in our own persons, that the intelligence which they imply is not in the individual beings that are endowed with them, but must be ascribed to the higher Power, from which they derive both their mental constitution and their muscular organs. The same observation applies to the complex movements, to be presently considered, which we regard as the natural effects of sensations.

The following general facts or principles demand attention in regard to the movements, whether instinctive or strictly voluntary, performed by the voluntary muscles of the human body.

1. They appear to be all the effects of muscular *contractions*. Voluntary relaxations are within the power of the mind, and are necessary to various movements, but do not appear, in the human body, to be in any case the cause of voluntary motions, although it is suspected that they are in some other animals.*

2. As the voluntary muscles are intended to move bones, and other solid parts, which are so articulated or connected with one another as to be susceptible of motion only in certain directions, and require considerable force to move them at all, so they have regular forms, and the direction and effect of their contractions are determined by these forms, by their position in the body, and by the other textures, especially the fibrous textures, with which they are connected. But every muscle can contract either partially or completely, with various degrees of force, and to various extent, and can combine variously with the contractions of other muscles; and therefore it is impossible, by merely studying the forms of muscles, and their origins and insertions on the skeleton, to understand the

* See Beclard, Anat. Gen. p. 564.

whole extent and variety of motions, which these muscles may communicate to the bones, and to the soft parts which the bones support.

3. The word Origin is generally applied to the less moveable extremity of a muscle, and the word Insertion to the more moveable, which is brought towards the other when the muscle contracts; but in some cases, the less moveable extremity of a muscle is fixed by other muscles, and it then acts on its origin, as when the abdominal muscles assist in depressing the trunk of the body, or when the genio-hyoideus and mylo-hyoideus depress the lower jaw.

4. Muscular fibres are generally placed obliquely to the line of direction in which the motion they communicate is to take place, being seldom rectilineal, often radiated, penniform, or compound penniform. From this two consequences necessarily follow, *first*, That they must exert a *greater* force to communicate a given extent of motion; *secondly*, That they will undergo a *less* amount of contraction in communicating that extent of motion, than they would have done if their direction had coincided with their line of action.

Farther, the oblique disposition of the fibres of muscles allows of their tapering form, and of their power being concentrated in narrow tendons, or on small points, and is therefore frequently important, both to symmetry and to convenience.

5. In studying the action of muscles on bones, and on the parts which these support or inclose, we consider the bone as a lever; the joint at which it is to be moved as the fulcrum; the muscle, acting at its point of insertion, as the power; and the weight of the parts supported by the bone, acting at their centre of gravity, as the weight or resistance, which the lever, moved by the power, has

to overcome. And in this view we observe, *first*, that the kind of lever employed in the animal system is generally of the third order, *i. e.* where the power is applied between the fulcrum and weight; *secondly*, that the point where the power acts is generally very near the fulcrum; and *thirdly*, that the line of direction by which the power acts, generally makes, in the beginning of the motion at least, a very acute angle with the lever. All these points are illustrated by attending to the insertions of the flexor and extensor muscles of the arm, fore-arm, thigh, and leg. In all these respects, the power of the muscles acts at great disadvantage in regard to the motion to be communicated; and the more so, as the muscles of the limbs are generally bound down by fasciæ, so as not to change their direction so much, and so advantageously, after the motions they cause have commenced, as they otherwise would do.

In these respects, as well as in the direction of the individual fibres of muscles, the arrangements are such as to economize the *length*, much more than the *strength* or power of muscular contractions; and are, besides, evidently adapted to prevent interference of one part of the body with another, to preserve symmetry of form, and permit elegance of movement.

6. In some instances, however, where the weight or resistance is very great, the lever employed in the animal economy is of the first order; as when the trunk of the body is either bent or extended on the articulations of the spine, by the abdominal muscles or extensors of the back,—or of the second order, as when the whole weight of the body is thrown on the toes by the elevation of the heel by the Tendo Achillis; and, in some instances, as in this last movement, and in the flexion of the body by the abdominal muscles, both the length of the arm of the

lever, by which the muscles act, and the angle at which they act, are much more advantageous than usual. The extension of the body by the muscles of the back, placed longitudinally along the spine, being an action in which the power acts by a very short lever, and often in opposition to gravity, requires a much greater strength of muscle than the flexion of the body does.

7. In performing many even of the most common movements of the human body, a definite combination and succession of contractions, not only of neighbouring muscles, but of distant muscles, associated into groups by their concurrence in these actions only, and by no anatomical relation, is often required. Thus the projection of the body at each step in running or walking quickly, requires a combined action of the extensors of the thigh, of the leg, and of the foot, in order that the metatarsal bones may be pressed with due force against the ground; this must be succeeded by an action of the flexors of all these parts, by which the limb may be raised and brought forward; and farther, in order that the equilibrium and erect posture may be maintained during these movements, a certain action of the extensors of the back, and certain motions of the arms, are necessary. By much attention, and frequently repeated trials, especially in youth, a great variety of combinations of muscular actions may be formed and associated, exactly in the same manner as those concerned in these common motions.

8. For the performance of most complex actions, not only various muscles, and associated combinations of the actions of these, but a certain adaptation of the form of the skeleton to the movements thus effected, are essential conditions; and various circumstances, in the form and disposition of the bones, are requisite for these purposes. For example, for maintaining the erect attitude

of man in all his movements, and at the same time rendering these movements easy and graceful, the following provisions, in the bony fabric, different from what are seen in others of the mammalia, are truly essential; *first*, That the lower limbs should bear a very unusual proportion to the whole body in length, and their articulating surfaces in breadth; *secondly*, That the pelvis should be unusually broad, and so hollowed internally as to give room for certain viscera, and through them support to others; and that the basis of support which it gives to the trunk of the body in the erect posture, should be farther enlarged by the length of the cervix femoris, which disengages the shaft of the thigh-bone from the hip-joint, and allows the limbs to be widely separated; while the head of the bone, within the acetabulum, being the centre of movement, the angular motion of the pelvis at each successive projection of the lower extremities is small;—*thirdly*, That the shaft of the femur be oblique and its inner condyle long, as well as its general direction vertical, so that its articulating surface at the knee may be perpendicularly under the pelvis in the erect posture;—*fourthly*, That the whole lower surface of the tarsus, metatarsus and toes, be at right angles to the leg, and rest on the ground in standing, so as to give a broad and firm support to the body;—*fifthly*, That the breadth of the bony fabric of the chest be greater than its depth from the sternum to the spine, whereby the arms are widely separated, and the centre of gravity of the trunk is thrown back;—*sixthly*, That the lumbar vertebræ and sacrum be large and strong, and the vertebral column disposed in a waving line, so that the viscera may be duly lodged and supported, and the centre of gravity be prevented from coming too much forward in the erect posture;—and *lastly*, That the foramen magnum, and the condyles of the occipital

bone, be situated about the middle of the head, and the eyes and mouth be directed forwards, so that the form of the head and face may be adapted to the erect posture. The peculiarities of the forms of the muscles attached to these parts in the human species, correspond strictly with those now stated in regard to the bones.*

The particular combinations of contractions of voluntary muscles, and movements effected by them in the other parts of the body, cannot be studied with advantage without the aid of preparations or drawings; but are well explained in the writings of Barclay,† Magendie, Arnott,‡ Roulin,§ Sir C. Bell, and Muller.

One curious department of this subject relates to the manner in which the different modulations of the voice, and different articulate sounds, are effected by voluntary movements of the respiratory muscles, and of the muscles of the Larynx, Velum, Pendulum, and Arches of the Palate, Tongue, and Lips, producing and varying sonorous vibrations in the expired air. It is ascertained that the posterior part of the tongue, the velum pendulum, and arches of the palate, as well as the muscles of the larynx (especially of the thyro-arytenoid muscles which stretch the ligaments of the glottis), are necessarily concerned in the modulation of the voice.‖ The chief agents in articulation are the lips and anterior part of the tongue.

* See Lawrence's Lectures on the Physiology and Natural History of Man.

† On Muscular Motion. ‡ Elements of Physics.

§ Journal de Physiologie, t. i. and ii.

‖ See Report by Cuvier, to the French Institute, on a Memoir by M. Bennati, 10th May 1830; and a case by Renauld, in Journal Heb. t. i. p. 66. Sir C. Bell's Bridgewater Treatise, and Baly's Muller, p. 972. *et seq.*

Besides what has been already stated, of contractions of different voluntary muscles taking place simultaneously in the performance of various instinctive actions, it is important to observe a tendency (not easily resisted), to what have been called *consentient* movements in many muscles of the body, *e. g.* in those of the face, with one another, and with the respiratory muscles in excited respiration,—in the extensors of the limbs, fingers, and toes,—in the corresponding muscles of the two sides of the trunk of the body, &c. This implies two things,—1. That in these parts the muscular sensations, by which the efforts of the will are limited to individual parts of the muscular frame, cannot be so distinct and definite as in the parts where the effort of volition is more easily insulated; and 2. That any vigorous effort of volition must be attended by a change extending to some distance in the cerebro-spinal axis, not absolutely confined to individual nerves.

The tendency to this simultaneous or consentient action is remarkably observed in the muscles moved, on the two sides of the body, by all the motor cerebral nerves, except the fourth and sixth, and in all the motor spinal nerves which supply the muscles on the trunk of the body. That it is not observed in the muscles of the extremities may probably be owing to the arrangements in the axillary plexus, and in the sciatic and crural nerves, by which every muscle in the extremities is connected with a considerable extent of the spinal cord, rendering probably, as already stated (p. 207), both the muscular sensations more precise and distinct, and the effect of an act of volition on any single muscle more forcible, than it otherwise would have been. It seems highly probable also, that the tendency to consentient movement in the muscles moved by the two nerves of the same pair, is the reason why the third pair

of nerves cannot be employed to give the movement outward to the eyeball, as it is to give the movements upwards, downwards, and inwards;—the movement outwards of one eye being always intended to be simultaneous with the movement inwards of the other, and therefore being put under the guidance of two nerves (the fourth and sixth) which can excite no other movement.*

A still more curious fact is well ascertained,—that efforts of volition, while they affect the muscles of voluntary motion, produce also an involuntary effect on muscles of involuntary motion, which have nerves from the same roots, although altered in their endowments, apparently by passing through ganglia. Thus the iris is uniformly excited to action when the will acts energetically, through the third nerve, on the muscles of the eyeball; and it is probably in the same manner, at least in part, that the heart is decidedly, and the alimentary canal more slightly, excited by frequent action of the voluntary muscles.†

The general effects of repeated and habitual exercise of voluntary muscles, on other parts of the animal economy, are of great importance, particularly in the prevention of disease. The following effects undoubtedly result from exercise, habitually taken, but within limits consistent with health.

1. The motion of the blood is habitually accelerated, and the heart excited to increased action, partly by the increased quantity of venous blood returned to it,—partly by the extension of nervous action from the motor nerves above noticed, whereby it acquires an increase of strength, and probably even of bulk.‡

* See Baly's Muller, p. 929. † Ib. p. 683 and 740.

‡ Some experiments of Magendie distinctly prove, that strong muscular exertion, particularly when attended with violent efforts of

2. The circulation on the surface of the body is habitually excited, and the excretion there, and probably at the lungs also, increased.

3. The circulation in the muscles that are exerted is particularly excited, and their bulk, as well as strength, gradually increased ; and both in consequence of this effect, and of that last mentioned, a considerable derivation of blood from the capillaries of other parts, especially internal parts, is no doubt effected.

4. The mental efforts requisite for continued and vigorous voluntary exertions, and the different sensations necessarily resulting from them, are incompatible with any continued exercise of the mental faculties on other subjects, and therefore often interrupt, or prevent, such trains of thought as might otherwise have occupied the mind.

It appeared from facts already stated (p. 308, *et seq.*), that such voluntary efforts as continue to be made by an animal, in which the medulla oblongata only remains in the cranium, are still effectual in exciting muscular contraction ; but that all indications of those more complex acts of thought, which precede and cause most of the voluntary efforts by which the muscles are moved,—disappear, at least in the higher animals, after the removal of the higher parts of the nervous system, and especially of the hemispheres of the brain. Hence it may naturally be inferred, that in most cases of voluntary actions, where the volitions exciting them are consequent on recollections and trains of thought (however short), some physi-

expiration, implying compression of the great arteries in the thorax and abdomen forces, forward the blood into the great veins rapidly and powerfully, at the same time that the flow along these veins is somewhat retarded by the disordered state of the respiration.

cal change is transmitted downwards, from the higher portions of the brain or cerebellum, to the medulla oblongata, and determines the peculiar action there, by which the voluntary muscles are excited; and it is reasonable to suppose that any such physical change, which these higher portions of the brain or cerebellum thus transmit downwards to the medulla oblongata, may be imitated by a mechanical injury.

These considerations enable us to understand how it should happen, as many experiments by Magendie and others have shewn, that in consequence of sections of different parts of the nervous system within the head, superior to the medulla oblongata, certain definite and combined actions of voluntary muscles are excited; such as apparently indicate, not that the muscles are moved involuntarily, as by irritation of their own nerves,—but that the will of the animal is constrained so to act, as to excite certain movements only. Phenomena exactly similar are occasionally observed in the course of various diseases of the nervous system.

The most uniform effects of this kind, observed in experiments on animals, have been a movement forwards, when the bands of medullary matter passing forwards through the Corpora Striata, from the crura cerebri into the hemispheres, have been cut through; a movement backwards, when the Cerebellum has been wounded or cut off; and a movement of rotation, to either side, when the bands of medullary matter passing through the Crura Cerebelli, to form great part the Tuber Annulare, have been divided on that side. And these facts seem to lead to the conclusion, that those acts of thought which prompt the volition to move in these different ways, act on the Medulla Oblongata for that purpose, through these different parts respectively. Perhaps we

should rather say, that the volition which acts on the flexor muscles, and causes the movement forwards, comes from the cerebellum; that which acts on the extensors, and causes the movement backwards, from the brain proper; and that which causes the movement to either side, from the opposite side of the tuber annulare. It is a fact ascertained by Flourens, and which must at present be regarded as anomalous, that section of the branches of the seventh nerve contained in the semicircular canals, in birds, produces movements of the head, horizontal or vertical, according to the parts injured, similar to those now mentioned in the trunk and limbs; which abate when the animal is at rest, but constantly recur when it attempts any motion.*

The loss of the Cerebellum in animals, particularly warm-blooded animals, appears from the experiments of Rolando, Flourens, and others, to be generally attended by a peculiar effect on voluntary motion. The animals, after this mutilation, provided that compression of the parts of the nervous system which are left is avoided, not only appear capable of sensation, but give all the usual indications of intelligence, and evidently exert volitions which throw many voluntary muscles into action; but they are unable so to regulate the contractions of their muscles, as to perform any definite voluntary action, excepting only those which are the most strictly instinctive, and the most closely linked with some of their sensations, such as biting and deglutition. All the voluntary movements of the body and limbs are performed in this state, in so irregular a manner, that they are generally ineffective for the purposes which are evidently intended; and most of the usual complex movements cannot be performed.

* See Ann. des Sciences Naturelles, t. xv.

This may be supposed to be, either because the injury produces certain permanent uneasy feelings, such as vertigo, which interfere with and confuse the sensations, by which the voluntary movements are regulated; or because the recollection of muscular sensations, which are the guide to all definite voluntary movements, depends upon the cerebellum, and is lost when it is destroyed, in like manner as the recollection of other sensations and mental acts appears to be lost when the hemispheres of the brain are destroyed.*

This last opinion may be thought to be supported by the fact, that in Man, where a greater number and variety of complex voluntary movements are learned by experience, and are associated in trains by means of the muscular sensations accompanying them, than in any other animals, the lobes of the cerebellum are more developed than in any other; and again, that in those animals which have, immediately after birth, the power of regulating their voluntary movements for definite objects, with the most precision, according to observations recently made by Sir W. Hamilton, the cerebellum is very generally found, at the time of birth, the most developed.

This is all that can be stated, at present, as to the parts of the nervous system which furnish the conditions necessary for the excitation, *first*, of the volitions by which the actions of the voluntary muscles are caused; and, *secondly*, of the muscular sensations, by which they are guided. When the volitions take place, it appears from facts already stated, that it is by changes which they effect in the medulla oblongata, anterior columns of the spinal cord, and motor nerves, that they produce the contractions of muscles.

* See Girou de Buzareingues, in Annales des Sciences Naturelles, t. xv. p. 52.

CHAPTER XVI.

OF THE INVOLUNTARY ACTION OF THE MIND ON THE BODY.

THERE is reason to think, not only that all mental acts are attended by some physical changes in the nervous matter itself, but that different mental acts (particularly any strong efforts of voluntary attention) produce effects on the state of the circulation through the nervous system. But all the decided effects upon other organs, which can be ascribed to mental causes, may be referred to the heads of Volitions and Instinctive propensities (already considered), of Emotions and Sensations. The effects of these last involuntary acts of mind, on the body, deserve more attention than they have received from most physiologists. They constitute one important element, which must be taken into account in considering various questions in pathology and therapeutics; and they may serve to give precision to our inquiries, into the physiological uses of those parts of the nervous system, which we have reason to suppose to be concerned in producing them.

The effects which can be distinctly ascribed to mental *Emotions*, are the following.

I. When acting *in full force*, they excite *strictly involuntary* motions of the voluntary muscles; of which we are conscious, because no contraction of voluntary muscles takes place, in the natural state, without a muscular sen-

sation informing us of its occurrence; but which we do not excite by any effort of our own, and can only control indirectly, either by fixing the attention on some other object,—and thereby superseding the emotion itself,—or else, by voluntarily exciting other muscular contractions, which antagonize those that we wish to conceal.

Of this kind are the complex actions of Laughter and Weeping, from the feeling of the Ridiculous, or from the emotion of Grief, however excited; and the slight contractions of the muscles of the face, and often of the body and limbs, by which mental emotions are expressed, and the interpretation of which has the name of Physiognomy. The movements of Sighing from sorrow, and of Yawning from listlessness, although traced to mental emotions, are more directly dependent on certain uneasy sensations.

These movements, as usually performed in the body, may be said to belong to the same class as the instinctive acts, already considered, by which appetites are gratified; but when the emotions prompting to them are of a certain intensity and duration, no voluntary efforts can be felt to intervene between them and the actions; and the most energetic efforts of volition are even ineffectual in exciting motions by which the action may be concealed.

The essential condition to the action both of laughter and weeping is a long, often interrupted, inspiration, succeeded by several short inspirations; the relaxation or ascent of the diaphragm being repeatedly stopped by short contractions of its own fibres, alternating with those of the abdominal muscles: with these movements are combined certain contractions of the muscles of the glottis and fauces, regulating both the escape of the air, and the sonorous vibrations of the air that escapes, from the wind-pipe; and likewise certain contractions of the mus-

cles of the countenance, and of those moving the lower jaw, which give *expression* to the action.

Besides these definite movements, which are nearly confined to the muscles of the face, neck, and chest, there are other contractions of voluntary muscles from mental emotions, which take place either generally over the whole body, or indiscriminately and irregularly in various parts, as in tremors from fear, or in the writhing of the body from the emotion of horror, or in the course of violent fits of laughter or weeping.

Farther, mental emotions of some strength and endurance, have a manifest influence on the energy of the strictly voluntary contractions, all over the body; some, such as Anger, Hope, Joy, increasing the muscular vigour: while others, such as Grief, Fear, or more correctly Despair, diminish it. There are examples of persons long paralytic, who have recovered the power over their limbs suddenly, when under the influence of violent emotions;* and there are many instances of great, although temporary, increase of muscular strength, from the influence of military ardour, and still more of religious enthusiasm or fanaticism.

These effects of the strength of contraction on voluntary muscles, cannot be referred simply to the increased or diminished strength of the circulation, which results from the same mental emotions, and will be considered immediately; because they sometimes take place almost instantaneously, and because other agents which affect the heart's action more powerfully, do not add equally to the vigour of the voluntary muscles. Nay, the emotion of fear often quickens and strengthens the heart's action, while it weakens the limbs.

* See Abercrombie, Pathology of the Brain and Spinal Cord, p. 308.

The effect of emotion on voluntary muscular contractions may be supposed to take place chiefly in that part of the process necessary to such contraction, which is confined to the nervous system; but as the effect is produced also on the actions of the heart, which are not excited through its nerves, we must suppose that great part of the effect is produced on the property of irritability, resident in the muscular fibres themselves.

It is to be observed, that this kind of effect of emotions on voluntary muscles is not produced on individual parts only, but *generally over the body*.

II. The different mental emotions produce decided effects on the Organic Functions of the body, and especially on the involuntary motions concerned in circulation, by which they are divided into exciting, such as Joy, Hope, &c. and depressing, such as Grief, Fear, &c.; and although these phenomena are too various and complex to be always reducible to distinct heads, yet this distinction may be recognised in most cases.

1. The effects of the Exciting Emotions or passions are widely different, according as they are of such a kind or degree as to act gently and uniformly for a length of time; or as they act suddenly and violently, and soon subside.

Such emotions as act permanently, and without violent agitation, *e. g.* the emotion of pleasure that attends any occupation which interests and occupies the mind,—the emotion of hope, from the prospect of lasting enjoyment, or of returning health,—the emotion of benevolence which attends the conferring, or that of gratitude, which follows the receiving, of benefits,—even the excitement produced by a certain degree of the feeling of indignation,—when of sufficient intensity and duration, and especially when

strongly contrasted with the previous state of the mind,—have a decided effect on the circulation ; which is chiefly observed throughout the capillary system. They cause a slight but permanent glow on the countenance, which contrasts with the paleness of grief ; they quicken the flow of fluids through, or the secretion on, the conjunctiva and cornea, and give brilliancy to the eye ; they perhaps elevate slightly the temperature of the surface, and certainly cause it to be less easily depressed by cold. According to the observations of Sanctorius and of Bryan Robinson, they increase the insensible perspiration by the skin ; and according to Dr Prout, they increase the quantity of carbonic acid thrown off at the lungs ; they promote the secretions, as is obvious from their influence in increasing the power of digestion, and securing the regular evacuation of the bowels ; and favour nutrition, as appears from their being generally found in connexion with increasing bulk of the body ; they have a well ascertained effect in protecting the body against the influence, not only of cold, but of malaria and contagion,—therefore against all the most powerful causes of acute disease ; they manifestly accelerate the convalescence from acute diseases, and are found very beneficial in various chronic diseases, in which debility is a prominent symptom. In these last instances, the effect of these emotions is to counteract causes which evidently weaken, and to assist other means, particularly the use of nourishing food, and agreeable sensations of warmth, or moderate alternations of temperature, which strengthen the body. The effect of these emotions is therefore gently and permanently, and often most beneficially, exciting or tonic, on the circulation ; and it is most distinctly observed in the vital actions that take place in the capillary system of vessels ;—the heart's action being little affected in most of these cases,—while,

in many other instances, both from mental and physical causes, the heart is manifestly excited without any of these good effects.

When any of the exciting emotions or passions act more suddenly and violently, their influence is chiefly observed in the heart, and larger arteries, where the blood is moved solely by the impulse of the heart; they cause increased pulsation, heat, and flushing, and a state like temporary fever, followed often by more or less of depression; but not attended by any of the beneficial effects on the secretions and excretions, and nutrition of the body, above remarked. The exciting emotion of anger, by its stimulating effect on the circulation, has often become the cause of dangerous or fatal disease. This effect on the heart's action, implying an increase of its irritability, according to what was formerly stated (p. 12), is more correctly expressed by the term *Stimulant* than *Stimulus*.

The effects of the more sudden and more violent passions are also more *local* than those of the gentler and more continued emotions. Thus the emotion of surprise, especially when attended with fear, excites the heart's action strongly, and thereby causes irregularities in the flow of blood in the larger vessels, and sometimes internal hæmorrhages; while it causes paleness and constriction, instead of flushing, on the surface of the body; and the emotion of shame has a powerful exciting effect on the circulation in the face and neck, without any such effect on other parts, even of the surface. The well known exciting effects of certain emotions on the secretion of the lachrymal gland; of others on that of the mammæ; and of others on that of the testes, are still more partial.

2. The feeling of listlessness or ennui, from want of mental occupation, and the feeling of permanent depression from continued sorrow, disappointment, or hope de-

ferred, produce effects on the circulation, especially in the capillaries, and on the secretions, just the reverse of those ascribed to a permanent feeling of hope or joy ; they make the face pale, the eye dull, the skin cold or easily chilled ; they diminish the amount of perspiration, and the excretion at the lungs, injure the digestion, and generally bind the bowels, and cause the body to decline in flesh and strength ; they favour the effect of cold, contagion, and malaria, in producing acute diseases ; and facilitate the attacks, and often frustrate the cure, of various chronic diseases, of which debility is an essential constituent.

Again, more sudden and violent Emotions of grief, fear, or despondency, or more fixed feelings, as those commonly expressed by the terms Horror, Disgust, Vexation, &c., often produce syncope, sometimes fatal syncope ; they have often a peculiar irritating effect on other involuntary muscles, the bowels, and bladder. Fear acts peculiarly on the vessels, and perhaps on the fibrous texture, of the skin ; and different passions affect variously and rapidly the secretions of the lachrymal gland, of the mouth, of the kidneys, sometimes of the liver, and more remarkably of the mucous membrane of the bowels, and probably of the stomach,—and so dispose peculiarly to diseases of the primæ viæ.

Farther, various emotions, at the same time that they affect, in these different ways, the organic functions of the body, excite distinct *Sensations*, sometimes pretty general over the body, sometimes confined to the parts principally affected, and which have been distinguished by the name of Sensations of Emotion. Thus a peculiar feeling of chilliness attends the constriction of the surface from fear or other mental feelings ; and the sensation of nausea, sometimes leading to vomiting, attends, in many persons, those emotions to which we give the name of

horror or disgust. Those persons in whom strong mental emotions, and effects consequent on them, in the circulation, and in other vital actions, have been excited by such means as tractors (real or fictitious), or the manipulations of animal magnetism, have generally felt acute sensations in the parts to which their attention has been forcibly directed. These sensations of emotion so uniformly attend the excitation of physical changes in this way, that it may be conjectured that it is through their intervention that emotions effect those physical changes; on which supposition, the agency ascribed to this class of mental acts would resolve itself into that of sensations, next to be considered.

This outline of the effects of Emotions on the different functions of the body, animal and organic, shews that they differ very materially from the effects of any voluntary acts, in the *extent of their operation* over the body, as well as in the variety of parts which they can affect. At the same time, it shews that, extensive as is the operation of these emotions, there are individual organs which each has a special power of affecting; a fact which is probably as little susceptible of explanation, as the special effects of the causes of our different sensations on the appropriate organs of sense.

The effects of these involuntary acts of mind are much more various in different individuals, than those of instinctive and voluntary efforts;—some persons are more easily affected by one kind of emotion, and others by another,—and some parts or organs of the body are more apt to suffer in one person than in another. In general, women and children are more under the influence of mental emotions than men are; and all persons are most under their influence at the times when their voluntary muscular powers are the weakest.

III. The effects, in the living body, which may be reasonably ascribed to Sensations, are very similar to, and in some instances identical with, those which we have ascribed to mental emotions.

1. As to their action on the Voluntary muscles,—the effect of the sensation caused by venous blood slowly pervading the lungs, in exciting the complex actions of inspiration and expiration, was fully considered already. The modifications of these movements in Laughter and Weeping, are produced not only by emotions, but also, in those in whom the nervous and muscular organs are much under the influence of involuntary mental acts, by the sensation of pain, and by the sensation of tickling, excited in any part of the body.

The long inspiration of Sighing seems to be merely the effect of the sensation in the chest being felt more strongly than usual, in consequence of respiration having been previously performed slowly and imperfectly for some time, generally on account of some mental emotion, or intense occupation of the mind, having prevented the sensation, which prompts to inspiration, from attracting the usual attention, or producing its usual effect.* Accordingly, it results from various mental acts or affections, besides the feeling of grief. The action of Yawning seems also to result from a sensation of lassitude or general uneasiness, which either succeeds fatigue, or results from inactivity of the body and mind; this last motion differs from the former chiefly in being followed by a longer and more forcible expiration, and in being attended by a definite movement of the muscles depressing the lower jaw, and by a less definite contraction of various other muscles of the trunk and limbs.

The actions of Coughing and Sneezing are among the

* See Darwin's Zoonomia, vol. i.

best examples of complex motions of voluntary muscles, strictly referable to sensations in the mucous membrane of different parts of the air-passages, and over which, when these sensations are in full force, the Will has no direct power. In both there is a long inspiration, followed by a sudden and forcible expiration, in which all the muscles that pull down the ribs and force up the abdominal viscera are called into action; but in sneezing both these movements are fuller and more sudden than in coughing, or in any voluntary motion of the same muscles. To both it is essential that the glottis be closed by an action of the laryngeal nerves, and arytenoid muscles, after the effort of expiration has commenced, so as to compress and condense the air in the chest, and then, that it be suddenly opened, so as to cause a sudden expansion, and give a sudden impetus to the current of air driven through the air-passages, and thus secure the expulsion of irritating matters; but in the act of sneezing, it is farther necessary that the current be directed through the nostrils, by the tongue being pressed against the palate, so as to prevent its escape through the mouth.

It is obvious, and important to remember, that neither of these movements can be correctly performed after an artificial opening has been made into the Trachea, or lower part of the Larynx, because such an aperture cannot be so closed and opened at pleasure, as to give the requisite impetus to the current of air.

The spasmodic movement of the diaphragm, called Hiccup, and the actions of Eructation, Regurgitation or Rumination, and Vomiting, by which different matters, and with different force, are rejected from the stomach, are likewise preceded, and appears to be caused, by certain sensations. In eructation, all that seems necessary is a relaxation, longer than usual, of the muscular

fibres of the œsophagus, allowing what lies at the cardia to arise to the mouth; but in the others, and especially in Vomiting, it is obvious that repeated and sudden simultaneous contractions of the diaphragm and abdominal muscles take place at the same time with the relaxation of the œsophagus, by which the stomach is strongly compressed, and its contents forcibly expelled. These contractions, in the case of Vomiting, are always preceded by the peculiar sensation of Nausea, which is often attended with more or less of faintness, or of vertigo; and as it becomes more intense, they are gradually and repeatedly excited. This sensation is followed also by a sudden and rapid flow of saliva, and generally of sweat; at the moment of vomiting the glottis is shut, and the velum pendulum palati raised and stretched as in deglutition; and the œsophagus assumes an inverted action.*

The experiments of Magendie have distinctly shewn, that in the act of vomiting, any contraction of the stomach itself which occurs, is hardly perceptible either to the sight or touch; that the simultaneous action of the diaphragm and abdominal muscles is sufficient to expel, in the same way, fluids contained in an inanimate sac, placed in the same situation as the stomach; and even that the expulsion of the contents of the stomach can be produced by a strong contraction, either of the diaphragm or of the abdominal muscles, excited by an emetic, when the other of these agents is palsied. At the same time, it is to be observed, that the appearance of bile, after a time, in matters rejected by vomiting, is enough to shew that a degree of inverted action of the stomach and duodenum must attend the movement. And it is pretty certain that there is an increased flow of the fluids of the stomach, as well as of the mouth, during vomiting.

* Beclard,—See Dict. de Medecine, Art. Vomissement.

It is important to remember, that the sensation of nausea may be excited in very various ways,—by certain substances introduced in any way into the blood,—by certain irritations of the stomach,—by certain impressions on, or diseases of, the brain,—by certain impressions on the nostrils, or the fauces,—by certain diseased states of the heart, bowels, kidneys, uterus, &c. ;—but in all these cases, when it attains a certain intensity and duration, the complex actions of vomiting follow.

The actions of voluntary muscles, by which the evacuation of the Rectum and Bladder is partly effected, were also stated as examples of the effects of peculiar sensations on this class of muscles. And in other instances, less definite contractions of these muscles are excited by sensations, as in the writhing of the body from pain, or from tickling the soles of the feet, the general tremors succeeding the sensations in the bladder and urethra which follow the discharge of urine, &c.

2. Various sensations evidently modify, nearly in the same way as emotions do, the action of different Involuntary muscles, which they cannot be said directly to excite. Thus the action of the heart is depressed or weakened by the sensation of nausea,—in some persons by certain smells,—and in all persons by the sensation of cold, when of a certain intensity and duration,—and by intense pain of a peculiar character, or resulting from affections of certain parts, from a blow on the epigastrium or testis, from inflammation of the bowels or kidneys, &c. ; and it is augmented by a grateful sense of heat after chilling of the surface,—by a different kind or slighter degree of pain,—by certain smells,—by grateful impressions on the palate and stomach, &c. The sensation of cold applied to one part of the surface, often causes constriction of the capillaries, and perhaps of the skin

over the whole body; and sometimes acts rapidly on the involuntary motions both of the intestines and bladder.

3. Sensations act equally as emotions, and variously, on different Secretions of the body,—on those of the lachrymal gland,—of the salivary glands,—of the stomach,—of the liver and kidneys,—and of the testes.

Those sensations which are pleasing and lasting, and not violent, especially if agreeably varied, appear to have a permanent beneficial effect on the capillary circulation and secretions, similar to that of the gentler exciting emotions; those which are more keenly felt, like the more violent emotions, affect individual parts peculiarly, but all of them shew a much more extended operation over the system than any individual voluntary acts can exert.

Many of the muscular contractions, and other changes, now described as the effects of Sensations, have been regarded by most physiologists as results and illustrations of what has been called Sympathy, or Consent of Parts in the animal system, whereby it is supposed that a change in the vital actions of one part of the body becomes the immediate cause of a change in those of another, although the actions of these parts have no immediate dependence on one another.

Thus, when cold water dashed on the face, or stimulating vapours applied to the nostrils, cause a sudden act of inspiration, it is said that there is a sympathy between the skin of the face, or membrane of the nose, and the diaphragm and intercostal muscles; when nausea and vomiting are produced by various changes in, or impressions on, the brain, nose, fauces, bowels, kidneys, uterus, &c., many physiologists have been satisfied with saying, that there is evidence of sympathies between these parts

and the stomach; and again, when nausea and vomiting have abated on certain changes being induced on the skin (as by the breaking out of a sweat, or appearance of an eruption), it has been said that this is an indication of a sympathy between the stomach and skin. So also when grateful food, or stimulating liquors, taken into the stomach suddenly, excite the action of the heart, it is said that the heart sympathizes with the stomach.

It is of great importance to possess accurate information as to the manner in which the connexion between different parts of the body, to which this name has been given, is established; because, when we attend to the manner in which various diseases are excited by their external causes,—in which different morbid changes succeed one another in the course of diseases,—and in which different remedies appear to influence the body,—we find that these changes are often more analogous to the phenomena usually called sympathetic, than to any others which the healthy body presents; and frequent reference is accordingly made to the principle of Sympathy in medical writings.

The subject of Sympathetic *Sensations* has been already sufficiently discussed; and it is with those *actions* only, of certain parts of the body, which are produced, as is usually said, sympathetically, or by reason of a sympathy with other parts, that we are here concerned.

Now, the following considerations seem sufficient to prove that the doctrine maintained as to this description of facts by Whytt and Monro,* and acquiesced in by Haller, is correct,—that the immediate cause of such changes is truly, as we have stated, a Sensation, which

* See Whytt's Observations on the Sympathy of the Nerves, and Monro's Treatise on the Nervous System.

always intervenes between the impression produced in the one part, and the change which follows in the other (or perhaps more correctly, is some action in the nervous system which is attended with, and makes itself known by, a sensation); and that the two parts sympathize with one another *only in so far* as the sensation which affects the one, is excitable by an impression on the other.

1. That the cause assigned, in this explanation of what are called Sympathetic Actions, is adequate to the effect ascribed to it, is sufficiently obvious from the fact, that the changes in voluntary muscles, in involuntary muscles, and in secretions, thus ascribed to Sensations, are not only closely analogous to, but in several instances identical with, those which are allowed on all hands to be excited by Emotions; which are mental acts bearing a close resemblance to sensations, and very generally attended or followed by sensations. Thus weeping and laughter may be excited in the irritable constitution of a child, as surely by a blow on the face, or by tickling the sole of the foot, as by any mental emotion; and when so excited, furnish as good evidence of sympathy between these parts and the respiratory muscles, as can be adduced to prove a sympathy between the nose and diaphragm.

2. All such phenomena as we here ascribe to Sensation, seem to coexist in the animal system only with indications of sensation. Movements may be excited in muscles, by irritation of their own fibres, or the nerves entering these, for some time after animal life is extinct, and when all the usual indications of sensation have ceased; but in these circumstances, no movements of the diaphragm result from irritation of the nose, fauces, trachea, &c., similar to those which were so readily excited by irritation of these parts while sensibility remained; and the different changes usually called sympathetic, are

slowly and imperfectly effected whenever sensibility is much diminished, as in the different comatose diseases.

3. In various instances, the Sensations, which we here regard as the causes of changes usually called sympathetic, may be excited by impressions made on *different* and distant parts of the body; and the actions which succeed them, in these different cases, are *the same;* which proves that these actions follow, not the irritation of any particular organ, but the excitation of a particular sensation. This is illustrated by the very various modes, in which the sensation of nausea, and the complex effects succeeding it, may be excited; by the excitation of laughter, on tickling very distant parts of the surface; by the influence of a sudden and intense sensation of cold,—in whatever part of the surface it may have been excited,—on the respiratory muscles, on the heart, and on the capillaries of the skin.

4. Conversely, when different impressions, made on *the same* part of the body, excite *different* Sensations, even although it may be certain that they are felt through the same nerve, they are *not* followed by the same action. Thus, of many sensations felt through the first nerve, only a few are followed by diminution of the heart's action, or by retching; tickling the fauces with a feather excites retching, but no such effect results from firm pressure against the fauces, nor from their painful inflammation; certain sensations in the nostrils and face, felt through the fifth nerve, are followed by full inspiration; but no such effect results from cutting, burning, or bruising these parts; certain sensations in the abdomen, as those excited by a blow on the epigastrium, or inflammation of the ileum, are followed by uniform depression of the heart's action; but many other sensations are strongly felt in the same parts, without any such effect resulting.

5. It has been already stated (p. 337) that when the mind is much engrossed, either by previous sensations, or by interesting trains of thought, any impressions on the organs of sense are transiently and imperfectly felt; no intensity of action taking place in two parts of the nervous system at the same time; and in these circumstances it is observed, that the effects in distant parts usually following such impressions, and ascribed to sympathy, are either suspended or imperfectly produced; which is farther proof that the intervention of the Sensation is essential to their production. Thus the actions of hiccupping, coughing, sneezing, even vomiting, or laughter from tickling,—when the sensations preceding them have not been very intense,—have often been observed to be arrested or prevented by sudden and lively impressions on other sensual organs, or by the excitement of intense mental interest on other subjects; and the same is true of the effects of cold applied to the surface, on the heart, or on the capillary circulation.

6. The remedies which have been found most effectual in stopping or preventing the actions usually called sympathetic, when in excess, are either such as make strong and new impressions on the organs of sense, and thereby, on the principle just stated, diminish the effect of sensations already existing; or else, such as blunt the sensibility in general, and therefore must be expected to diminish all effects of Sensation.

7. Another peculiarity of such actions, denoting their origin in mental acts, is, that they are remarkably obedient to the law of Habit, being more easily excited where they have repeatedly and recently taken place; as is seen particularly in coughing, sneezing, and vomiting; the short train of mental acts, consisting chiefly of sensations, but often including slight voluntary or instinc-

tive efforts, which precedes any one of these motions, is easily reproduced by association, after a few repetitions.

Thus it appears, that when any vital action, or alteration of action, in one part of the body, is said to be the result of Sympathy with another part, the fact is in general more correctly expressed by saying, either that the two parts are affected by some sensation which acts on both alike, or that some Sensation, which is the natural effect of an impression on the one part, is the natural cause of an action at the other.

Some physiologists, particularly Dr Marshall Hall and Mr Grainger, think they give a sufficient explanation of these phenomena, by ascribing them to the Reflex function of the medulla oblongata and spinal cord ; and consider Sensation as a frequent attendant indeed, but not a necessary constituent, of such actions.

It is this last part only of this doctrine, which can be regarded as new, because, if the inference already stated, as that drawn by Cuvier, and apparently with good reason, from the experiments of Flourens (drawn also by Magendie from his own),—that the spinal cord and medulla oblongata are the only parts of the larger masses of the nervous system essentially concerned in Sensation,—is admitted, all who ascribe sympathetic actions to sensation, must necessarily regard them as dependent on these parts, and on actions carried back to them and again forward from them.

But if the considerations above stated are allowed to have weight, they must be allowed to shew, that it is an imperfect and erroneous view of these actions, which excludes Sensation from the account given of their excitement, in the natural state. And although it is true that impressions made on the extremities of sensitive nerves, sometimes excite contractions of various and dis-

tant muscles in paralytic persons, or in animals so mutilated as to be probably devoid of sensation, yet there is no good evidence that such *regular combinations and successions* of muscular contractions, as are requisite for the performance of the sympathetic actions, or of any instinctive actions adapted to particular ends (what some physiologists call "movements of adaptation"), are ever produced in the absence of sensation.*

Again, many physiologists have supposed, that what have been called sympathetic actions, may be explained anatomically, by peculiar connexions among the nerves of the sympathizing parts; and it seems to be the opinion of Sir Charles Bell, in regard to the movements of the respiratory muscles (which are so generally and so variously excited in this way),†—and is also stated more generally, although in a more qualified manner, by Mr Mayo,‡—that the circumstance of nerves being connected, not in their course, but at their origin, gives a peculiar tendency in the parts supplied by these nerves to sympathize; or affords an explanation of the fact, that a sensation, felt through one of these nerves, excites a muscular movement, or some other change, through the other.

But various considerations, several of which were stated on this subject by Whytt and Monro, seem equally conclusive against the supposition of such connexions in the vital actions of different parts, depending on connexions of nerves, in their course, or at their roots.

1. We have already seen, and must regard it as a leading fact in regard to actions of this class, that it is *not*

* See Volkmann on Reflex Motions in British and Foreign Medical Journal, July 1838.

† Exposition of the Nervous System, pp. 54, 76, 88.

‡ Outlines of Physiology, 2d edition, p. 343.

every impression made on the sensitive organ concerned in any such case, which is followed by the change in a distant part, but only *those impressions* which excite a particular Sensation ;—that other impressions, although felt through the same nerve, if they excite different sensations, have no such effect ;—and again, that impressions on other parts, felt through other nerves, if they excite the same sensation, have the effect. Now, no effect, which is thus variable and occasional, can be ascribed to a cause which is uniform and permanent, such as a connexion of nerves, whether in their course or at their roots.

2. Although there are various cases (enumerated by Mr Mayo), where a nerve, certain of the sensations of which are followed by a change in a distant part, arises very close to the nerve of that other part, yet this is by no means a general law. For example, some of the most striking sympathetic actions in the body are those excited in the diaphragm, intercostal muscles, and abdominal muscles, by impressions on the sentient extremities of the fifth and eighth nerves, as in the varied actions of breathing, coughing, sneezing, vomiting. But the phrenic, dorsal, and lumbar nerves, by which these actions are known to be excited, are not so closely connected at their root with the fifth and eighth nerves, as several other motor nerves are, which are not affected, or only very slightly affected, in these movements. Again, several motor nerves arise nearer to the origin of the olfactory, than the phrenic and dorsal nerves ; but it is by these last that vomiting, when produced by smells, must be excited ; and the third, fourth, and motor part of the fifth, arise nearer to the origin of the optic nerve than the seventh does ; but a portion of this last nerve, moving the orbicularis oculi, is much more surely excited by bright light impressing the retina, than any of those other nerves are.

3. Conversely, there are many instances of nerves closely connected at their origin, the parts supplied by which shew no tendency to sympathize. No particular effect is ever seen on the motor part of the fifth nerve, supplying the elevators of the lower jaw, from impressions made on the branches of the sensitive part of the fifth, which supply the nostrils, eyeball, and forehead, though other and more distant nerves are very easily excited by impressions on these parts. The whole of the spinal nerves are associated at their origin, by arising from the same columns of medullary matter; but when an impression is made, and sensation excited, in one of the sensitive cerebral nerves, that sensation extends its influence along the spinal cord, *selecting* some of the spinal nerves, which it excites, simultaneously or alternately, in the movement to be produced, and *passing over* others, which have just the same connexion with the part where the impression was made. The lower cervical, and first dorsal nerves, which supply the axillary plexus and the arm, are very generally passed over in this way, when sensations excited through the sentient nerves of the brain throw into action the phrenic nerve above them, and the intercostal nerves beneath them; but the anatomical connexion of all these spinal nerves with the sentient cerebral nerves is the same.

We conclude, therefore, on the whole, that the actions or changes usually called Sympathetic, whether in voluntary muscles, involuntary muscles, or secretions, are, in general, effects of Sensations; dependent, of course, on the medulla oblongata and spinal cord, which are the parts of the nervous system most essentially concerned in sensation; and that sensations have a much more extended influence along the spinal cord and nerves, in exciting such changes, than any single voluntary efforts have: but that no anatomical reason can be given for the fact.

that each of these sensations acts upon certain nerves only.*

The peculiar effect of certain sensations on individual muscles, or individual organs, is often very troublesome, or even dangerous, and tends to no beneficial effect, in disease; *e. g.* in the case of coughing from incipient inflammation of the bronchiæ, tenesmus from inflammation of the rectum, faintness from inflammation of the stomach or small intestines; but a final cause for the peculiar sympathetic effect of each sensation, in the healthy state, may in general be easily traced; and we should suffer much more from the want of the connexions, thus established among the actions of our different organs, than we do from their occasionally inconvenient operation.

Some general observations remain to be made on the involuntary agency of mind on body, in the animal frame.

I. It is a curious fact, that the changes thus produced in one individual, are *instinctively interpreted* by others. It is plain, that the effects of Sensation and of Emotion, on the countenance, on the respiratory muscles, on the attitudes and gestures, are no sooner seen than they convey to the spectator a notion of the mental state of the person experiencing them; and several reasons may be given for thinking that this interpretation is not the result of experience.

1. These signs of mental affections are evidently very early understood by young children; sooner than any fixed associations can be supposed to have been formed, by experience, of their connexion with any particular modes of conduct.

* For farther illustration of this subject, see a paper on the Physiological Principle of Sympathy, by the Author, in Edinburgh Medico-Chirurgical Transactions, vol. ii.

2. These *natural signs* of strongly felt emotions or sensations affect us both more quickly and more powerfully, than the expression of them by words, or other *artificial signs* does; which would not have been the case if both modes of expression had owed their significance only to experience, and therefore been on the same footing.

3. To one who attends to them minutely, the varying expressions of countenance, manner, and voice, in a person under the influence of strong unaffected feelings, convey *more meaning*, and denote nicer varieties of these feelings, than we have words to express; or than experience can have taught.

The rapidity and precision with which the natural signs of the passions are interpreted, are most strikingly illustrated in observing the effect of theatrical representations, and especially of pantomimes; where it is obvious, that although few individuals acquire the power of correctly imitating the effects of strong emotion or feeling, yet no man has any difficulty in interpreting and appreciating its correct imitation.*

The final cause, or use, of many of the effects of Sensation and Emotion on the body, particularly of such as shew themselves externally, is to be found in this interpretation of them by other men. The provisions of nature, in the constitution of each individual of the human species, are not confined to his own immediate wants; they extend to his adaptation for social intercourse; to the relief of his sufferings by the sympathy, and the increase of his enjoyments by the participation, of others; and to the cordial union and co-operation of numbers, in prosecuting objects, and surmounting difficulties, for which the exertions of individuals would be inadequate.

* See Stewart's Elements, vol. iii.

II. This becomes still more obvious when we consider, that, along with the instinctive, or at least very rapid, interpretation of the natural signs of Sensation or Emotion, there is more or less of a natural or *instinctive disposition to imitate* these, in the person who interprets and is affected by them.

What has been called the Principle or Desire of Imitation is exemplified strongly, and has been considered by some as exemplified only, in the strictly voluntary actions; as in the case of children, who "copy the voices of their companions, their tones, accents, and modes of pronunciation; and learn, insensibly, to model their habits, on the appearance and manners of those with whom they are habitually conversant." But it is even more strongly marked, at least in constitutions very susceptible of changes of this kind, in regard to many phenomena which come under the head of Involuntary Agency of mind on body; as in the case of yawning, laughing, weeping, even nausea and vomiting, fainting, involuntary motions of the face and eyes, and involuntary contractions of the body and limbs in different spasmodic diseases. The spectator, in these cases, first interprets these movements as an expression of some emotion or feeling in the actor, and then assumes somewhat of the same feeling himself; and then this assumed feeling produces somewhat of its natural effect on his own system. In some cases, the emotions arising from the sight of the expression, or even the sure anticipation, of suffering in another, produce likewise slight but distinct *sensations* in the spectator.

The degree in which the mind of the spectator, in such cases, participates in the feelings of the actor or sufferer, depends on various circumstances, the influence of which is easily understood, and is of real importance in the con-

duct of life. It depends on the nature of the emotion or feeling expressed ; the gentler emotions being in general most easily communicated from one person to another, while the rougher passions excite less sympathy when suddenly presented ; but if gradually infused into the mind of the spectator, rouse him to stronger emotions, and often to a more permanent and cordial imitation and aid of the person whose words or actions excite them. It depends on the circumstances in which the expression of emotion or feeling is observed, which are sometimes such as, by suggesting a short process of reasoning, interest the mind of the spectator strongly, and at other times not. It depends on the susceptibility of impression and of change in the Nervous System,—remarkably different in the two sexes ;—and on the character and state of mind of the spectator, especially on the degree in which his mind is open to new impressions, and unembarrassed by previously prevailing thoughts, as in early youth,—or accustomed to various impressions, and preoccupied by habitual attention to other objects, as in more advanced life. And it depends also, very remarkably, on the number of spectators. For when the emotion which agitates an individual is reflected from the countenances, and expressed by the voices, of many around him, its intensity, and the tendency it gives to imitation of those by whom it is expressed, are naturally multiplied by the extended operation of this principle.*

Hence the most striking examples of the natural interpretation, and instinctive imitation, of the effects of violent emotion or passion, are always seen in large assemblies of men ; and the excitement of courage, or the diffusion of panic, among soldiers, the extremes of party violence, the absurdities of religious fanaticism, the pro-

* See Smith's Theory of Moral Sentiments.

pagation of various disorders of the nervous system in schools, prisons, or hospitals.—are all illustrations of the principles now stated.

When we compare the evils with the benefits which we derive from the disposition, existing more or less in every individual of our species, to sympathize with, and participate in, the feelings of those around him, we can have no doubt that the benefits infinitely outweigh the evils. But it is important to be aware of, and prepared for both.

III. Although there is still considerable obscurity as to the parts of the Nervous System essentially concerned in this involuntary agency, which certain mental acts unquestionably excite in the living body, yet several leading principles regarding that subject may be stated with confidence, as results of experiment and observation. It is obvious that the nervous system must be constructed with a view to the influence of Sensation and Emotion on the animal frame, equally as to the production of Sensation, or the effect of acts of Volition; and accordingly, what has been ascertained on this subject goes far to explain the intention of some of the most complex arrangements of the nervous system.

1. We know that the changes in the nervous system which attend Sensations and Emotions, and through which those mental acts affect the different organs of the body, must take place primarily and chiefly in the medulla oblongata and spinal cord, and in their posterior portions. No impression made on the extremities of any sentient nerve excites any motor nerve to action, unless it has been carried back to the spinal cord, and excited a reflex action there; and when the spinal cord has been destroyed, none of the changes in the body, which usually

follow and indicate sensations, are ever observed.* On the other hand the removal of the brain and cerebellum in animals that survive the operation, does not suspend those muscular actions; and probably those contents of the cranium are not farther concerned in the kind of nervous action now in question, than as the brain appears to be necessary to the *endurance* of sensations, and to all *recollections*, and emotions resulting from recollections;† and therefore must greatly augment the frequency and intensity of the changes connected with these mental acts.

2. We know that when Sensation has been excited by an impression communicated through sentient nerves, to the spinal cord and medulla oblongata, or when recollections and Emotions of mind (and concomitant sensations) have affected these parts, their influence may extend instantaneously over the whole cerebro-spinal axis,—exciting certain muscles to action,—modifying the irritability of all muscles,—altering the condition of the skin all over the body,—and increasing or diminishing the secretions of various and distant parts; and this extensive influence of many sensations (*e. g.* of Heat or Cold, of Nausea, of intense Pain or Pleasure) is of essential importance in the animal economy. This extended operation of such mental acts is quite in accordance with observations by Volkmann and others on decapitated animals, in a state of unusual excitability, in which an impression on a single sensitive nerve, once carried back to the spinal cord, was found to excite the whole motor nerves and voluntary muscles of the body.‡

* See Marshall Hall's Lectures on the Nervous System, p. 18, 19, 26, 27, and Volkmann in British and Foreign Medical Review, July 1838, p. 213.

† See p.208, *et seq.*

‡ British and Foreign Review, July 1838, p. 215.

To the kind of nervous action which attends Sensations and Emotions, and produces these varied and extended effects, the general name *Sensorial Influence* may be given, and some of the laws, according to which it acts, may be tolerably well defined.

3. We know that, in so far as this Sensorial Influence acts on the *capillary circulation and secretions*, it must *pass downwards along the sensitive nerves* of the part; for it is distinctly seen to be suspended in the eye, by injury or disease of the 5th nerve,* and takes place remarkably in glands (particularly the lachrymal glands and mammæ) which have hardly any nervous fibres entering them, except those of common sensation.†

4. In so far as this influence affects *muscles of voluntary motion*, we know that it may excite them when they are palsied to voluntary efforts; as appears from the continuance of the action of respiration,‡ coughing, sneezing, vomiting, even yawning and stretching,§ and sometimes of the contractions of the muscles of the face in laughing or weeping;|| and this not only in palsy, depending on disease of the brain, but in that almost universal palsy, which depends on disease of the anterior columns of the cervical portion of the spinal cord;¶ which shews that this sensorial influence can pass downwards, even to the voluntary muscles, by other channels than those by which the efforts of volition are transmitted.

* This was distinctly observed in a case of complete palsy of the 5th nerve on one side, in the Edinburgh Infirmary, some years ago.

† Baly's Muller, p. 675.

‡ Bell's Exposition, &c. p. 212.

§ Abercrombie in Bell's Appendix to Papers on the Nerves, p. 120.—Similar cases have occurred to the Author.

|| Magnus in British and Foreign Review, Oct. 1837, p. 501.

¶ Bell's Appendix to Papers on the Nerves, p. 408.

5. We know that impressions, made on sensitive nerves in the lower part of the body, may excite distant muscles, by a reflex or sympathetic action, if the lower part of the spinal cord be entire, although it is separated from the medulla oblongata (see p. 208); while, on the other hand, it is also known that this reflex action can take effect on voluntary muscles only through their motor nerves;* which shews that this sensorial influence can cross from the sensitive to the motor columns, not only at the medulla oblongata, but at any part of the spinal cord.

From these facts, it may be inferred, at least with much probability, that this sensorial influence passes downwards, along the lateral and posterior, *i. e.* the larger portions of the spinal cord; and acting from thence, affects muscular parts through motor nerves, and capillaries and secreting parts through sensitive nerves; whereas the influence of the will, coming only from the brain, passes downwards only by the anterior columns, and anterior roots of the spinal nerves.

6. We know, what is in accordance with these facts, that motor nerves, which are peculiarly under the influence of sensations and emotions, are found, in various instances, to have roots in the sensitive, as well as in the motor, columns of the spinal cord; and some which appear obedient to this involuntary agency only, in the former exclusively. Thus the 3d and facial nerves, both exclusively motor, but portions of which are remarkably influenced by sensations, have been found by Sir C. Bell to have roots from behind, as well as from before, the grey matter of the cerebro-spinal axis;† and all the motor portions of the 8th pair originate chiefly, and the spinal accessory (which is clearly motor, but probably not subject

* Volkmann in British and Foreign Review, July 1838, p. 213.

† Edinburgh Philosophical Transactions, vol. xiv.

to the will) exclusively, from the posterior portion of the spinal cord.

7. Although we cannot pretend to explain why the change in the sensitive portion of the cord, which attends any particular sensation, should cross to the motor portion of the cord only at certain points, and thereby excite only certain muscles; yet, as we know that sensation resides principally at the medulla oblongata, we can understand that those effects of sensation on muscular parts, which are intended to be produced by sensations of slight intensity, should be produced through nerves passing off from that part of the axis; and therefore why the motor nerves supplying the muscles most essential to deglutition and respiration should very generally have their roots from the neighbourhood of that part. This is also in accordance with the observations of Volkmann on Reflex Action, which, when excited by *slight* irritations, affects only the motor nerves adjoining the sensitive nerve which is irritated.*

8. In accordance with what was formerly stated as the result of experiment as to the use of Plexuses, we must suppose that those muscles or other organs will be most easily affected by the sensorial influence, which have their nerves from the greatest number of points in the spinal cord; thus the multiplied origins of the spinal accessory, and of all the nerves that arise from the cervical plexuses, will enable even slight sensations, acting through them, to affect the muscles of respiration and deglutition sufficiently; and thus the arrangements of the ganglia and plexuses of the sympathetic nerve, which place all the organs supplied by it in connexion with all parts of the cerebro-spinal axis, must *concentrate* upon the organs which it supplies (*i. e.* upon all the principal organs of

* Loco cit. p. 213.

organic life), the influence of changes which extend so rapidly and generally along the spinal cord, as we have shewn, that the changes attending Sensations and Emotions certainly do.

Thus a part at least of the intention of the complex arrangements of nervous fibrils, passing, like fine galvanic wires, from every part of the spinal cord to the heart or other viscera, becomes sufficiently apparent.

That the effect of changes in the spinal cord on the heart's action is really multiplied by the numerous communications of the nerves of the heart with all parts of the cord, appears distinctly from the experiments of Le Gallois and Wilson Philip on the effect of injuries of the spinal cord and brain on the heart's actions, formerly mentioned (see p. 187-8); and also from some experiments of Dr Reid,—in one of which the effect of violent injury of the brain on the heart's action was rendered much less than usual by previous section of the par vagum and sympathetic in the neck; while in others it was quite obvious, that even after that section the Emotion of Fear produced much of its usual effect on the heart.*

9. We know that this sensorial influence affects many muscles which the will cannot affect, and that in so doing, it must traverse many *ganglia;* but what is the intention of the interposition of the grey matter of a ganglion,—whether to intercept the influence of the will, while it transmits the sensorial influence,—or to give additional power to this last influence,—or to effect both purposes, is still doubtful.†

* Edinburgh Medical and Surgical Journal, 1838, p. 158.

† In favour of the first supposition, it may be observed,—

1. That all the ganglia are now generally admitted to have filaments from the anterior or motor, as well as from the posterior or sensitive roots of the spinal nerve; notwithstanding which, the will does not, in any instance, produce its specific effect on any nerve

It is certain, however, that the effects which we have ascribed to the sensorial influence in the body over the functions of circulation and secretion, are produced through the ganglia on the roots of the sensitive nerves, and many of them through the ganglia of the sympathetic likewise, because they are produced on organs which have nerves from these sources only;[1] and it seems a fair inference from the frequency of ganglia on the nerves of the viscera, and the absence of ganglia from the nerves of the special senses (as well as from the sensitive nerves of fishes), that the use of those on the posterior roots of the spinal nerve has reference to the transmission of the sensorial influence downwards along these nerves, not to the excitement of sensations by changes propagated upwards.*

which has passed through a ganglion, nor does mechanical irritation of such a nerve excite the muscles it may supply.

2. That it appears, nevertheless, from what was stated (p. 365) as to consentient movements, that efforts of volition, transmitted—certainly in the case of the ciliary ganglion, and probably in all others—through these motor nerves, have a certain involuntary effect on the muscles supplied by ganglionic nerves; and it is very remarkable, that this effect is greater on the ciliary nerves and iris, where the ganglion traversed is small and single, than in the cardiac nerves and heart; and greater on them than on the splanchnic nerves and intestines, where a multiplicity of ganglia have been traversed.

3. That it seems to be a general fact, that nervous fibres which pass through any considerable quantity of grey matter have their endowments remarkably changed by doing so. The sensitive nerves which have passed through the ganglia of the sympathetic convey, in the natural state, but obscure sensations of touch, or of pain, in comparison of other sensitive nerves, but they are chiefly appropriated to the sensations of anxiety, dyspnœa, nausea, faintness, &c., which have no such determinate positions as the sensations of touch have. Still more remarkably, it may be observed, that the endowments both of the sensitive and motor columns of the spinal cord are found to have been changed, after they have traversed the grey matter of the tuber annulare.

[1] See Marshall Hall's Lectures, p. 30.

Muller supposes that the grey matter in the ganglia and in the ganglionic nerves *presides over* the organic functions of capillary circulation, secretion, and nutrition; but it seems improbable that these functions are influenced by nervous actions only through the grey matter, because the nerves of the lachrymal gland and of the mammæ, which command the secretions of these glands so remarkably, pass through very little grey matter.

In so far as the sensorial influence affects muscular motion, it is probable that it does so chiefly through the filaments from the anterior columns of the spinal cord which enter the ganglia; but as we know that the iris is affected by section of the fifth nerve, and of the sympathetic, as well as of the third nerve,* we are certain that the influence which thus affects muscular organs may be transmitted in part, by sensitive as well as motor nerves, and is probably heightened by these varied modes of transmission. This influence, as exercised over involuntary muscles, is in general different from the mere excitement of a muscle to contraction; it consists more generally in augmentation or diminution of the property of irritability; and was imitated, in experiments of Muller, not by mechanical, but by chemical irritation of the cœliac ganglion in animals, giving an unusual rapidity to the peristaltic motions of the intestines for some time;† and it is certainly most remarkably produced in muscular organs, such as the heart, which are not directly excitable through their nerves. It seems highly probable that this kind of influence on muscular parts may always be transmitted through sensitive as well as motor nerves; but whether it originates in the grey matter of the ganglia, or is merely transmitted through them, we are not yet informed.

* See Magendie, Journ. de Phys., t. 4, p. 177, 309; Reid, Edin. Journal, 1838.

† See Baly's Muller, p. 664.

There appears to be nothing visionary or hypothetical in what has been here stated as to the manner in which this sensorial influence is excited and is transmitted in the living body, although the precise office of some parts of the nervous system in regard to it is still uncertain.

The expression often used on this subject, that the ganglionic nerves *preside* over involuntary motion and organic life, is vague and ambiguous; but, in the minds of many who use it, implies that these nerves, or an influence conveyed through them, are essential to the performance of the organic functions, which is manifestly an hypothesis, open to various objections, formerly stated.

But when we say that various arrangements of the nerves, and especially of the ganglionic nerves, are intended, in the natural state, to bring the organs which they supply under the control of involuntary acts of mind, we attribute to these nerves no agency different in kind from that which all physiologists ascribe to nerves, as the instruments of mental acts; we specify the kind of mental acts to which these nerves are subservient, (viz. sensations and emotions); and by reference to the facts just stated, we go so far in assigning the reason, both of the peculiarity of their structure, and of the complexity of their origin and course. According to the one doctrine, the ganglionic nerves are sent to certain moving and secreting parts, to enable them to contract and to secrete; according to the other, it is only asserted that they are sent thither to subject their motions and secretions to occasional change, from certain involuntary mental acts, of which all animals are susceptible; and which are notoriously, and for useful purposes, endowed with the power of affecting simultaneously many functions of the body, which the will cannot affect.

CHAPTER XVII.

OF SLEEP.

It was formerly observed, that the necessary alternations of repose and activity in the functions of the Nervous System, to which we give the names of Sleep and Waking, bear so great an analogy to the alternations of rest and motion in living muscles, as to favour the supposition of some active changes, and probably movements, continually taking place in the nervous matter, in the state of waking, which either cease or undergo a change in sleep; and we cannot doubt that some physical change in the nervous system attends the transition from the one of these states to the other. But these, like all other changes in the nervous system, corresponding to the healthy changes of the Animal Functions, are known to us only by their effects or accompaniments; so that all we can do, in treating of this subject, is to state what has been observed of the conditions which essentially characterize sleep, of the circumstances in which it naturally occurs, of those which favour or impede its occurrence, and of the results which follow it. The following are the most important facts that have been observed on this subject.

1. Natural sleep is essentially characterized by the change that takes place in the Animal Functions during it, and especially by the Suspension of all Voluntary Power, not only of that habitually exerted over the voluntary muscles, but also of that exercised over the trains of thought in the mind (see p. 340). The power of sensation is not suspended; respiration, dependent on

sensation, continues; instinctive movements of the limbs, consequent on a constrained posture, take place; any unusual impressions on the senses are felt, and even subsequently remembered; and any strong, sudden impressions are so effectual as to interrupt sleep. But all sensations are blunted; respiration consequently becomes slower and fuller; slight impressions on the senses fail of their wonted effect; no effort of voluntary attention to any of these impressions is observed; and if we attend as carefully as possible to the state of our minds when sleep is approaching, we observe that we are gradually losing the power of fixing our attention on, and detaining before minds, any particular object of thought; and that, in proportion as we do so, the images of external things, which pass before our minds, assume the character of reality.*

2. The organic functions go on during sleep, but are differently affected in different parts of the body. The actions of digestion and assimilation are apparently promoted by it; perhaps chiefly because the exercise of the limbs, and of the senses, which continually promote, during waking, the circulation in the extremities, and on the surface of the body, and so retard these internal actions, is suspended. In hot climates, where the effect of exertion to promote the circulation on the surface is greater than in cold; sleep, after the principal meal, especially if of animal food, seems essential to easy digestion. On the other hand, the action of the heart becomes somewhat slower, and perhaps somewhat weaker, during sleep, probably merely from the want of the stimulating influence of sensations and voluntary exertions. The power of the voluntary muscles, as appears from their condition after wakening, is somewhat enfeebled by their inactivity.

* See Stewart's Elements, chap. iii. and v.

The perspiration and excretion of the lungs, and the evolution of animal heat, are somewhat diminished. The surface of the body is more easily chilled; and the body becomes more liable than previously to the influence of various causes of disease, the first effect of which is to depress the capillary circulation, especially on the surface.

3. The state of relaxation, or suspension of the animal functions, which constitutes sleep, is, in the healthy state, merely the consequence of the activity of the changes going on in the nervous system during waking; the disposition to it is stronger as these, within certain limits, have been more numerous and greater; and it is promoted by whatever withdraws the causes that habitually excite the voluntary activity of the mind;—therefore, by withdrawing all causes of lively sensation, by darkness, by silence or gentle and uniform sounds, by the absence of all pain, or of any strong impressions on the senses of Touch, Taste or Smell, by an agreeable temperature, and by mental tranquillity.

4. The tendency to sleep is evidently promoted, in different cases, by causes which increase the flow of blood towards the head and its impetus on the brain; especially if they be not such as to excite at the same time the activity of the mind; but according to the observations of Blumenbach, the turgescence of the vessels of the brain, when that is exposed to view, appears to be diminished during sleep.

5. After sleep the senses are more lively, the train of thought probably more rapid, and all voluntary mental exertions are easier and pleasanter than before; but the strength of the circulation, especially on the surface of the body, and the full power of the voluntary muscles, are not completely restored until food is taken.

6. In the most profound sleep, the mental acts (excepting only slight sensations, such as those prompting inspiration), are either at a stand, or leave no trace on the memory; but the state of the mind called Dreaming, which is remembered more or less distinctly after wakening, is very common during perfectly natural sleep: and is sufficiently characterized by the two circumstances already noticed, that the succession of thought, though often modified by any sensations that may occur, is not regulated by the will, and that the images which pass before the mind are considered as realities.

7. From 6 to 8 hours in the 24 are occupied by sleep, in most adult persons; but the length of time thus spent, requisite for refreshing the body, is not strictly proportioned to the amount of exertion made during waking; and may often be gradually and beneficially abridged by habit, as well as by any desire, strongly impressed on the mind before sleep commences.

The state of imperfect sleep called Somnambulism, seems to be characterized by a partial restoration of the power of the will over the voluntary muscles, and over the mental operations, while some part of the mental delusion attending sleep continues; and especially, by a suspension of some of the principal associations, which were wont to regulate the succession of thoughts; so that the person does not recall the past thoughts or images which objects presented to him would naturally suggest, and neither talks nor acts as he had been accustomed to do; although his mind acts with great energy, and sometimes with unusual power, on certain subjects. When he awakens from this state, which he does in general as suddenly as from natural sleep, the usual associations of thoughts in his mind being restored, he retains little or

no recollection of what had passed during it. This state has sometimes lasted long, or recurred repeatedly, and in precisely the same form. A similar state of partial and temporary hallucination, with suspension of some of the usual associating principles, sometimes occurs from disease, generally in the course of some of the less violent diseases of the nervous system ;—is sometimes brought on by drinking strong liquors ;—and has often been produced, in certain constitutions, by strong mental emotion, especially when heightened by numbers, as in the ceremonies of some sects of religious enthusiasts, or by the practices of those who profess Animal Magnetism. Whether in this last case any influence, really emanating from the body of one person, can contribute to the effect upon another, independently of the excitation of a strong mental emotion, is very doubtful.*

There is every reason to believe, that this state of somnambulism, reverie, or extase, depends on some peculiar physical change in the condition of the Nervous System, just as the natural state of sleep, and the more usual forms of delirium do; but none of these states can be ascribed solely to alterations, either of the circulation in the brain, or of the pressure on it, or of its own texture; and as all other changes in the condition of the Nervous System, whether healthy or morbid, are known to us only by their effects, it is in vain to attempt more in regard to this anomalous state of the functions of the brain, than to determine the circumstances in which it occurs, and the phenomena by which it is essentially characterized.

* See the works already mentioned on Animal Magnetism—Darwin's Zoonomia, Art. Reverie; and Abercrombie on the Intellectual Powers, &c. sect. 3, chap. iv.

CHAPTER XVIII.

OF GENERATION.

This function is the most complex, and has been called the most mysterious, in the animal economy; because the formation in an animal, of another being, similar to itself, and capable of maintaining a separate existence, is an effect of its vital action, which nothing that we see on examining its structure, or any of its other functions, would have enabled us to anticipate that it would produce. But in every other department, not only of physiology, but of science in general, when we have ascertained the conditions under which a phenomenon takes place, we must admit that its appearance, after all these conditions are fulfilled, is equally inexplicable.

This function is very variously managed in the different orders of living being. The only condition essential to all cases of generation that have been fully investigated, is the separation of a small portion of the organized frame of a living being previously existing, which portion is capable of subsequently maintaining a separate existence.

But in Man, and in all the higher animals, several distinct subordinate conditions are essential to this purpose, the number of which increases as we ascend in the scale of beings. These are,

1. The formation, in a particular organ, of a germ, or small organized body—to be afterwards developed into a separate animal.

2. The fecundation of this germ, which seems to be always effected by the application of a seminal fluid; and

implies a distinction of sexes, whether on the same or on distinct individuals.

3. Copulation, which is an essential condition only where it is required that the fecundation should take place, before the germ is detached from the body of the female ; *i. e.* in all the mammalia and birds,—in most reptiles, – in some fishes,—and many of the lower tribes of animals.

4. Utero-Gestation, which is essential only where it is necessary, not only that the germ should be impregnated within the body of the female, but that it should draw its nourishment, during a part of its development, from the fluids of the female ; *i. e.* in the mammalia, the only true viviparous animals.*

The organs destined for the two first of these purposes, —for the formation and fecundation of the embryo,— although existing from birth, are fitted for their function later than any others (the usual age of puberty in this climate being at from 14 to 16 years) ; and they become unfit for it again in women at from 45 to 50 years of age, in men at a considerably later and less definite age.

The circumstances in regard to the anatomy of the testes in the adult, which chiefly demand attention here, are their position within the scrotum, and isolation from the surrounding textures by two serous membranes, the tunica albuginea and vaginalis,—their connexion with the rest of the body by the spermatic cord, consisting chiefly of vessels and nerves which descend from high in the abdomen, and by the cremaster muscle surrounding the other parts of the cord, by which the testes may be drawn upwards, and the flow of their secretion along the vasa deferentia probably promoted ; their vascular texture, and the very numerous convolutions of their excre-

* See Cuvier, Leçons, &c. t. v.

tory tubes. These have first the name of *Tubuli seminiferi*, which are coiled up in bundles between the septa, formed by firm cellular substance in the body of the testis: then of *Vasa recta*, which lead out, one from each of these bundles, to the plexus called *Rete vasculosum*, at the back of the testis; then of *Vasa efferentia*, leading from it into the *Epididymis*, where they are again convoluted, and unite at the *Vas deferens*, which is first coiled up in the epididymis, but ultimately emerges in a strait direction, and has a long and circuitous course up the spermatic cord, through the abdominal ring, and by the side of the bladder and vesicula seminalis, till it penetrates the prostate gland, and terminates at the origin of the urethra.

The vesicula seminalis appears to consist of a single canal, much convoluted, and which secretes a mucous fluid; and it seems certain that both this fluid, and that of the prostate gland, must be forced out chiefly at the time of the passage of the semen, and be discharged along with it; but although it appears probable, that a reservoir may be provided for the seminal fluid, similar to the gall-bladder for the bile, it has not yet been ascertained whether the vesiculæ seminales, in those animals where they exist, answer this purpose.

When the testes enlarge at puberty, and their secretion is fully formed, the sexual appetite is first felt; and at all subsequent times, the presence of a quantity of that secretion in the long and convoluted course of the seminal ducts, and perhaps in the vesiculæ, is one condition essential to its being strongly felt, and that, on the amount of which the degree of its intensity is mainly dependent.

At the same time, the other changes characteristic of puberty take place,—the growth of hair on the organs of generation, in the axillæ, and on the lower part of the

face, the enlargement of the larynx, and alteration of the voice, an increased development of the chest and shoulders, as compared with the pelvis, an increased energy of mental disposition, and manifestation of the peculiarities of the male character,—probably connected with an increased development of some portion of the nervous system within the cranium.

These changes are not merely simultaneous with the secretion of semen, but dependent upon it; for they are all prevented from taking place by castration; but whether the sensations and emotions, consequent on the establishment of the secretion, or whether the secreted fluid itself, absorbed into the blood, may be regarded as the stimulus to nutrition in these different parts, is uncertain.*

Although the presence of the secretion of the testes is essential to the existence of the sexual appetite, yet that mental feeling is not immediately excited by any changes in the testes, or seminiferous ducts, and the sensations by which it is accompanied and characterized, are referred to, and are connected with physical changes in, the corpora cavernosa and glans penis. They are on a footing with the sensations of emotion, formerly mentioned;—as the change in the circulation of these parts is on a footing with the other changes in the circulation, which we formerly referred to mental emotion. But when this feeling has been excited, it has likewise a manifest action on the testes themselves, and greatly promotes the secretion there.

The mental feeling, or Emotion of Desire, which has

* The case of the young man born blind and deaf, recorded by Mr Stewart (Transactions of Royal Society of Edinburgh, vol. vii.), appears to favour this last supposition, for all the usual marks of puberty had taken place in him, when he had never shewn any marks of sexual desire.

these effects, is probably connected with some portion of the cerebellum ; because it has been often observed to exist in an unnatural degree, in cases of disease or injury of that part ; but we have already seen evidence that the cerebellum is also concerned in very different functions ; and it is very improbable, that the whole of that organ should be devoted to the excitation of this single feeling. It would appear, that the change in the state of the Nervous System, within the head, which attends this feeling, is imitated by the compression of the brain, which results from stagnation of the blood in the jugular veins, because erection, and even emission, very frequently accompany death by strangulation.

The duration and intensity of this mental feeling are remarkably influenced by the mental law formerly noticed, according to which no two mental acts of importance can coexist ; and it is accordingly often rendered ineffectual for its purpose by the concurrence of other feelings ; for example, of hypochondriacal apprehensions.

The manner in which the distention of the corpora cavernosa, corpus spongiosum urethræ, and glans penis, is effected, under the influence of this feeling, is still somewhat doubtful. The blood is evidently received into large cells in this texture, but anatomists are not agreed as to whether these cells are truly exterior to the circulation, or merely dilatations of the small vessels. Neither are they agreed as to how the stagnation of blood in the penis is effected ; but it has been found, that in large animals, such as the elephant, the nerves of the penis (which are always large, and originate from several of the sacral nerves, and from the sympathetic) form plexuses in an unusual way about the large veins on its dorsum ; and Magendie found that ligatures of some of these veins produced a partial distention of the corpora

cavernosa. These facts render it probable that a vital constriction of these veins, determined by an action of the nerves, is its main cause; and Dr Houston has lately demonstrated small muscles and tendons, situated behind the arch of the pelvis, distinct in some of the lower animals, and visible, although more rudimentary in man, by which the great vein leading from the penis is encompassed, and may easily be compressed.*

The effects of this distention of these parts are,—that the canal of the urethra is straitened and narrowed; that the general direction of the urethra forms a less angle than before with the extreme part of the vasa deferentia, by which the semen enters it, and a greater angle than before with the direction of the orifice of the bladder, by which the urine enters it; and that the form of the whole organ, and the sensibility of the glans in particular, are adapted to their office in the generative function.

The mental feeling which prompts the whole of these changes, heightened by the sensation of these parts in their distended state, ultimately excites both the flow of the semen along the vasa deferentia, and likewise the spasmodic action of the levatores ani and acceleratores urinæ, by which the emission is effected, and which has been vaguely ascribed to a sympathy between these muscles and the urethra.

It is well ascertained by the microscopical observations of Leuwenhoek, Haller, Spallanzani, Prevost and Dumas, Magendie, and many others, that a number of vermiform animalculæ, capable of apparently spontaneous motion, are to be seen in the seminal fluid of all animals, when these are in a state fit for procreation. The advocates of equivocal generation, however, maintain, that these do not actually exist in the semen in the living body,

* See Dublin Hospital Reports, vol. iv.

but are the result of its very rapid changes after death or removal from the body, which they regard as the consequence of its peculiar and intense vitality.*

Although the whole of the female organs of generation,—the uterus, and its broad and round ligaments, the Fallopian tubes, vagina, and external parts, as well as the ovaria, are formed from the time of birth, they are more fully developed at the age of puberty, not only simultaneously with, but in consequence of, the development of the ovaria at that time; and the other changes which then takes place, and especially the enlargement of the pelvis, growth of the mammæ, establishment of the menstrual discharge, and manifestations of the female character, are also believed to be dependent on the change in the ovaria; none of them having taken place in cases on record, where these organs were found to have been only rudimentary. Whether these changes may be dependent on the absorption of something from the ovaries, or whether the sensations and mental feelings connected with the active state of the ovaries are concerned in producing them, is unknown.

The menstrual discharge takes place from the inner surface of the uterus, in the healthy state, every four weeks, lasts about three days, amounts to six or eight ounces, and consists, so far as has been yet ascertained, of blood in a great measure deprived of its fibrin. It is generally preceded and attended, especially about the time of its first establishment, by some degree of pain of the back and abdomen, often of the head, and frequently by dyspeptic, nervous, or febrile symptoms; which abate as it goes on, and gradually subsides; but are aggravated if it is suddenly checked.

* Burdach, Physiol. § 84.

As the continuance of this periodical discharge coincides very generally with the time during which women are adapted for childbearing, it seems evidently to be a consequence of the active state of the organs of generation. As it very generally ceases during pregnancy and nursing, it has been often thought to be a succedaneum for the discharges from the system, which take place during these states; and as it has not been ascertained to consist of any thing beyond the usual constituents of the blood, and is manifestly increased, as morbid hæmorrhages are, by causes of general and local plethora, and diminished by means which obviate these, it has been supposed that it is to be regarded merely as a natural hæmorrhage.

But, on the other hand, as the effects resulting from the sudden suppression of this discharge, are generally more serious than those which follow the stopping of any simple hæmorrhage, or other evacuation of the same amount; and as such suppression has often been followed by hæmorrhages from parts very little disposed, in general, to such a form of disease,—or by various inflammatory or nervous disorders,—there is reason for suspecting that this evacuation is intended, not merely to keep down the quantity of blood in the system, but to secure the evacuation of something formed in the system during the active state of the genital organs, and which would be hurtful if retained.

Dr Lee has recorded several cases, from which he thinks it probable, that, at every monthly period, an enlargement and rupture of one of the Graafian vesicles in the ovaria take place, simultaneously with the increased flow of blood to the lining membrane of the uterus; *i. e.* that changes then occur, strikingly similar to those which take place in conception.*

* Cyclopædia of Practical Medicine, art. Ovaria.

The visible change upon the ovaria, which takes place at puberty, consists chiefly in the formation or development, in them, of the small cysts called Graafian Vesicles, which contain a mixed fluid, and are the essential part of their structure; each containing and nourishing an *ovum*, which, however, in all the mammalia, is small in comparison with the cyst containing it, and was therefore only lately detected in the ovary of those animals, and first distinctly described there by Baer, whence it has been called the vesicle of Baer. But in them, as well as in the oviparous animals, it appears that this ovum consists of three parts,—the containing membrane, or sac of the yolk, the yolk, or *embryotrophe*, and the germ or embryo, and that this last consists originally of two parts, the germinal layer, a granular substance lying immediately beneath one part of the sac of the yolk, and the germinal vesicle, or vesicle of Purkinje, lying in contact with this layer, and containing a transparent fluid.*

The changes which take place in these organs, at the time of sexual intercourse, and particularly the great congestion of blood in them all, must no doubt be ascribed to the influence of sensations and mental feelings; but the precise extent of the effect of these is uncertain.

Observations on animals, and in some instances on the human body, distinctly prove, that at the time of such sexual intercourse as is followed by conception, the fimbriated extremities of the Fallopian tube embrace the ovarium, so as to make a single, though very winding and irregular, passage from it to the external parts; and that thereafter one of the Graafian vesicles, extending itself to the surface of the ovary, bursts and discharges the smaller vesicle or ovum, which descends along the Fallopian tube into the uterus. The germinal vesicle

* See Allen Thomson, Cyclopædia of Anatomy, &c. art. Generation.

within the ovum is also ruptured at this time, if the changes in the mammalia are similar to those in the bird, and its contents incorporating themselves with the germinal layer, form the *germinal membrane, blastoderma*, or *membrane proligere*, in the centre of which there is then a transparent spot, and which is afterwards transformed into the embryo.* But there is more doubt and difference of opinion as to the following points.

1. It has been disputed whether the escape of an ovum from the ovary can take place in the human body, or in others of the mammalia, without impregnation. The numerous observations of Haller, and of Prevost and Dumas, shew that this happens only in a few of the lower animals of this class; but the observations of Valisneri, Santorini and Bertrandi in Italy,† and of Sir E. Home and Dr Blundell ‡ in this country, seem sufficient to prove, that, in the human body, as in some of the lower animals, vesicles may be detached from the ovaries, and that the marks now to be mentioned may sometimes be subsequently found there, where there had been no sexual intercourse.§

When a vesicle has been ruptured, and ovum detached from the ovary, it leaves at first a ragged cavity, containing a little blood; but this gradually assumes the appearance of an irregular yellowish granular substance, called a corpus luteum, with a cavity within it, and corresponding cicatrix on the surface of the ovary, which afterwards becomes gradually less distinct. But, according to the observations of Sir E. Home, of Magendie,||

* See Burdach, Physiol. § 63. Martin Barry, in Edin. Medical Journal, 1837.

† See Blumenbach, in Comment. Soc. Reg. Scient. Gotting. vol. ix.

‡ Phil. Trans. 1837, and Physiological Researches.

§ See Allen Thomson, loco cit.

|| Precis Elementaire.

of Baer, and others,* a yellowish substance appears to be sometimes formed around one of the Graafian vesicles, before it bursts, and may continue, after the escape of its contents, gradually encroaching on, and ultimately obliterating, the cavity left.

It would appear, therefore, that the total absence of any corpus luteum may be regarded as a proof that no recent conception had taken place; but it is certain that the presence of a distinct yellow body in the ovarium, may be independent of the growth of an embryo in the uterus;—depending either on the escape of an ovum without sexual intercourse, or, in some instances, on the development of a vesicle containing an ovum which has not yet escaped, or perhaps on slight disease.

2. It is not fully ascertained how far, in the winding canal, closed by the adhesion of the fimbriæ to the ovary, it is essential that the male semen should penetrate, and whether its contact with the ovum, or vesicle detached from the ovarium, is necessary in order that it may impregnate the ovum.

That its contact with the ovary itself is not necessary to the discharge of the ovum, appears not merely from the facts already stated, but also from many experiments by Dr Haighton and Dr Blundell, made on rabbits, in which animals there are two uteri corresponding to the two ovaries. In these experiments, different portions of the canals leading from the external parts to the two ovaries, were obliterated by adhesive inflammation, and sexual intercourse afterwards permitted, and the escape of vesicles from the ovaries was clearly ascertained to have followed that intercourse.†

On the other hand, that the seminal fluid must neces-

* Breschet's Repertoire d'Anat. et Physiol. 1829.

† See Blundell's Physiological Researches.

sarily reach the ovum in the uterus, in order to vivify it, seems to be rendered highly probable, *first*, By the farther result of the experiments of Drs Haighton and Blundell, in all of which it appeared, that, although ova were detached from ovaries, the communication of which with the external parts had been interrupted, yet such ova never were developed into embryos ; while those from the opposite ovaria, received into the opposite uteri of the same animals, were so developed ; *secondly*, By the observations of Galen, Ruysch, Cheselden, Haller, Hunter, and many others, who found the male semen in the uteri of different animals killed soon after copulation ; and especially by the microscopical examinations of Prevost and Dumas,* who satisfied themselves of its always existing, in these circumstances, about the horns of the uterus, but could never detect it in the Fallopian tube : *thirdly*, By the analogy of many animals of the classes of Reptiles and Fishes, in which it is certain that the deposition of the male semen on the ova, at the time of, or after, their discharge from the body of the female, is the essential condition of their development ; and *lastly*, By numerous experiments by Spallanzani and others, in which the seminal fluid, even diluted with water, applied to the ova of many animals, was found to effect an *artificial fecundation* of them.

If this be so, the rare cases of extra-uterine conception, where the ovum is developed either in the Fallopian tube, or beyond its extremity, must be cases where a portion of the seminal fluid has penetrated further than usual along the canal leading to the ovary.† And that

* Annales des Sciences Naturelles, t. i. ii. iii. and xvi.

† Cases of extra-uterine conception were published by Mr Langstaff and Dr Elliotson (Medico-Chirurgical Trans. vol. vii. and xiii.), in which the Fallopian tube was obstructed ; but the facts now stated

this may happen, we can understand from the observation of Dr Blundell and others, that, at the time of intercourse, the whole of that canal is in a state of spontaneous movement. This last fact likewise enables us to understand, consistently with this doctrine, how impregnation should have taken place in several cases on record,* where the vagina was preternaturally narrow, or the hymen nearly entire.

On the other hand, in opposition to the doctrine of absolute contact of the seminal fluid being required, we must state, that, in the case of birds, a single intercourse is known to be sufficient to impregnate many eggs, which are laid successively after it; and it is difficult to understand how the semen should have been conveyed to the ovary for that purpose. In many insects and other animals low in the scale, the influence of one sexual intercourse extends to several generations. In the case of the reptiles and fishes, the seminal fluid is rarely deposited directly on the ova,—a layer of mucus being very generally interposed. Experiments have been recorded, in which artificial impregnation of female animals, by semen taken from male animals, is said to have been effected (by what has been called the Seminal Aura), where the male fluid did not come into actual contact with the uterus of the female;† but these seem to be very generally distrusted. Actual contact, however, cannot be held to be essential.

3. The time when the ovum leaves the ovarium, and descends along the Fallopian tube, is not certainly known,

render it most probable that the obstruction had been subsequent to conception.

* *Ex. gr.* in Memoires de l'Acad. des Sciences, 1712; Edin. Med. and Surg. Journ. vol. i.; Medico-Chirurg. Trans. vol. ii.; Foderé, Medicine Legale, § 252 and 986; Burdach, Physiol. t. ii.

† Edin. Med. and Surg. Journal, vol. xix. p. 485.

and probably not uniform; but the observations of Prevost and Dumas, Magendie, and others, shew that, in various animals, it is not for some days, and that in the human species it may probably be eight or ten days, after the sexual intercourse with which it is connected.

Thus it appears, that the visible changes in all viviparous animals, at the time of the intercourse which is to be fruitful, are confined to the deposition of the seminal fluid in the uterus, and the adhesion of the fimbriæ to the ovary; and that the detachment and passage of the ovum or vesicle into the uterus, take place within some days after; during which time, Prevost and Dumas found the seminal animalcules to be distinctly visible in the uterus; which led them to conjecture, that the implantation of one or more of the animalcula on the ovum may be the necessary condition to its development.

After such an intercourse, the inner membrane of the uterus is found to be lined all over with an effusion of flocculent lymph, part of which stretches across the cervix uteri, and closes its mouth, and the formation of which is not dependent on the passage of the ovum, nor even on the admission of semen into the uterus; for it has been found, both in cases where the conception was extra-uterine, and in experiments where the vagina was obstructed.*

In this flocculent lymph, the ovum, when first seen, is loose and detached; it is much smaller than the vesicle which disappeared from the ovary;† and, according to almost all observers, it appears as a sac containing a limpid fluid, on one side of which the embryo becomes visi-

* Blundell, loco cit.

† Prevost and Dumas, loco cit.; and Cruickshanks, Phil. Trans. 1797; Baer, loco cit.

ble, not sooner, probably, than three weeks after conception.

The covering of the ovum, when the parts become more distinct, appears to consist of two membranes, the outer of which, called the Chorion, is of loose texture, and its exterior flocculent surface has the name of Spongy or Shaggy Chorion; while the inner, called the Amnion, is smooth and uniform. The lymph lining the uterus, and in contact with the shaggy chorion, also appears separable into two parts; the outer of which is called Decidua Vera, and the inner, supposed by Dr Hunter to be turned back by the entrance of the ovum, has been generally called, since his time, Decidua Reflexa.

The mode of formation of this last membrane has been much disputed by Breschet, Velpeau, Granville, and Lee. A case described and delineated by the last author,* and another analogous to it, which occurred in the Edinburgh Infirmary, shew pretty clearly, that it is not a reflexion of the uterine decidua, but is formed by accretion of the flocculent matter then filling the cavity of the uterus, around and under the influence of the ovum, and is therefore more properly called Ovuline Decidua.

In the course of the second month, the shoots of the shaggy chorion, on one part of the ovum, implant themselves firmly in the corresponding portion of the decidua, generally towards the fundus of the uterus, and form the Placenta, and the rest of the flocculi of the chorion then disappear. The embryo is found after a time to have detached itself from the side of the ovum, and floats in the liquor amnii, the proportion of which to the whole ovum is afterwards gradually diminished; and the only attachment of the embryo to the membranes is then found

* Medico-Chirurg. Trans. vol. xviii.

to be the umbilical cord, by which it is connected with the placenta.

But for a time, before these changes are completed, there is a small sac containing a whitish fluid, called Vesicula Alba, or Umbilical Vesicle, between the amnion and chorion, and, according to the observations of Baer, Allen Thomson and others, it appears that this vesicle, not the amnion, is the inner portion of the ovum which descended from the ovary, corresponding, therefore, to the sac of the yolk in the bird, and connected, like it, with the abdomen of the embryo by vessels called Omphalo-Mesenteric. This differs, however, from the corresponding structure in the bird in this, that, instead of being taken into the interior of the abdomen as the growth of the embryo advances, it is rather separated from the embryo, by the lengthening of the vessels connecting them; and shrinks and disappears as the umbilical arteries and vein passing beside it, and connecting the embryo with the shoots of the chorion beyond it, are gradually enlarged.

The Placenta, formed at first by the implantation of the chorion on the membrane, which has been thrown out on the inner surface of the uterus, is therefore at first not vascular, but when fully developed, appears as a spongy mass composed chiefly of vessels, infinitely subdivided and convoluted. It has been often stated that a part of this vascular structure is continuous with, and may be injected from, the arteries of the uterus, and this has been called the Maternal Portion; but that another portion, towards the inner surface of the placenta, can be injected only from the vessels of the umbilical cord of the fœtus, and this has been called the Fœtal Portion. According to the recent observations of Dr Lee,* it would

* Phil. Trans. 1832.

appear, that the whole Placenta may be injected from the vessels of the Fœtus, and that whatever passes into it from the uterine vessels, must transude through the very thin membrana decidua, from the uterine sinuses, or large veins; many of which appear to have slits or semilunar openings, on the inner surface of the uterus, at the part where the placenta is attached. This statement appears to be somewhat exaggerated, but it is certain that the vessels passing into the Placenta from the Uterus are small, and of such tenuity, that they must allow of free transudation, that part of the blood transudes directly by the openings above mentioned, and that the circulation in the maternal portion of the placenta, although very active, must be chiefly of the *diffused* kind.* It is probably, therefore, by transudation only, that the contents of the uterine vessels pass into the minute branches of the umbilical vessels; and it seems certain that no entire globules of blood are transmitted from the one set of vessels to the other, because the globules of the fœtal blood appear, from the observations of Prevost and Dumas, to be differently shaped from, and in the later stages to be larger than, those of the adult.

In experiments by Magendie and by Dr Williams,† it appeared that camphor, and that oil, injected into the blood of pregnant animals, were soon detected in the blood of the fœtus; but poison injected into the umbilical arteries, although mixing with the blood on its way from the fœtus to the placenta, did not affect the mother. Neither does fatal hæmorrhage in the mother apparently diminish the fulness of the vessels of the fœtus:—so that it would seem that the transmission of fluids in the placenta is almost entirely from the mother to the fœtus.

* See Velpeau, Embryologie Humaine, p. 70; Ramsbottom, in Medical Gazette, 1834; Rigby, in London Medical Journal, 1835.

† Edinburgh Medical and Surgical Journal, vol. xxv.

In the case of many lower animals, as the mare and the cow, there appears to be no passage of blood from the uterus to the placenta, but vascular processes from the two surfaces are interwoven, though nowhere incorporated, with one another; and the nourishment must be effected by transudation from the one set of vessels to the other.

The placenta is in no case an organ for the *transfusion* of blood from the mother to the fœtus; but serves as a *reservoir* of nourishment, supplied by the mother, from which the vessels of the fœtus absorb certain matters, and form fœtal blood, specifically different from that of the adult.

The placenta must also answer, in some measure, the purpose of arterializing, as well as supplying, the blood of the fœtus; but the difference between the blood in the umbilical arteries, coming from the fœtus, and that in the umbilical vein passing into it, is never nearly so great as that between venous and arterial blood in the adult; and to this it is partly owing, that all the functions of the Nervous System are nearly at a stand in the fœtus, but are excited into action immediately after birth.

The gradual formation of the different organs during the life of the fœtus, has been lately much studied throughout the whole scale of creation, as well as in the human body, and the growth of various parts minutely described. Some general observations only on this subject can be made here.

1. It is certain that the different parts of the fœtus do not result merely from *evolution* of organs already existing in the ovum; but from movement of the fluids, and agglomeration of their particles at particular points, to *form* different solid textures of defined forms, under the influence, no doubt, of the same vital properties to which we give the name of Vital Affinities, on which the nourish-

ment of these textures at all subsequent times depends. Many well known parts of the different organs, such as the heart and brain, are distinctly seen to be added after other parts have attained a considerable size. The ovum, when it first descends into the uterus, has two coverings, the outer of which, whether originally formed in the ovary, or, as others assert, added during the descent from the ovary, becomes the chorion, and the inner becomes what was described as the Umbilical Vesicle. This last membrane is first thickened at one part by the accretion of the germinal membrane within it, then this thickened portion separates into distinct layers; these are thrown into folds; and these folded layers of membrane gradually undergo conversion into the different textures composing the animal body; the amnion and liquor amnii at the same time forming around them.* The outer or serous layer constitutes the greater part of the body, the inner or mucous layer is converted into the alimentary canal and adjoining glands, and the substance interposed between them into the vascular, the pulmonary, and genito-urinary organs.

2. The commencement of the formation of organs in this way is anterior to the first formation of the heart, and to the development of vessels on the umbilical vesicle; and the part of which the rudiments are first seen is the vertebral column.

3. The mode of growth of the embryo of the mammalia, before the formation of the placenta, is strictly analogous to that of the embryo of the other vertebrated animals, the umbilical vesicle, and vessels passing from it

* See the papers of Baer, of Allen Thomson, and of Prevost and Dumas; Burdach's Physiol. t. 3, and Art. Generation, by Dr Allen Thomson, in the Cyclopædia of Anatomy; Martin Barry, Researches in Embryology, Phil. Trans. 1838.

into the embryo, corresponding to the sac of the yolk and omphalo-mesenteric vessels in the chick; and the only essential difference being, as already stated, that the sac of the yolk is ultimately received into the body of the chick, whereas the umbilical vesicle, as it shrinks and gives place to the umbilical vessels and placenta, recedes from the body of the embryo. Whether an allantoid membrane, continuous with the bladder, is also expanded on the surface of the ovum, for the exposure of the blood to air, as in other animals, during any part of this period, is doubtful. It is certain that, in many other respects besides the mode of its nutrition, particularly in the structure of its nervous system, and organs of circulation and respiration, the embryo of the mammalia in the early stages of gestation, is strikingly analogous to the permanent structure of the lower vertebrated animals.* But some of the analogies of commencing structure in different classes of animals, on which much stress has been lately laid by comparative anatomists, seem to be fanciful, and some of the speculations connected with them may be distrusted.

It is here to be observed, that the life of the embryo is absolutely dependent—as that of the chick in ovo is—on nourishment passing into the interior of the ovum; the albumen ovi, in the one case, gradually incorporating itself with the vitellus, and part of the matter secreted from the inner surface of the uterus, in the other, being gradually absorbed by the shoots of the shaggy chorion, even at that early period when these, according to the observations of Raspail and of Velpeau, are cellular, but not vascular.† There being no vessels provided for the commencement, nor even for some time for the support,

* Tiedemann, Serres, Allen Thomson, &c.

† Embryologie Humaine, &c. p. 14.

of these movements of fluids, on which the nourishment of the embryo is dependent, they have been ascribed to the principle of Endosmose. But they take place in circumstances where no such movements occur, unless the embryo be alive; and therefore they ought to be referred to the head of Vital Attractions and Repulsions. Nor is there any other moving power to which we can ascribe the formation either of the blood or blood-vessels, or of any parts of the embryo, on the germinal membrane.*

Again, at a more advanced period, we see a manifest and powerful determination of the maternal blood to a particular spot, caused by the vital actions of the fœtus there going on (as is clearly shewn by the case of extra-uterine conception), and maintaining a copious transudation of portions of the blood, out of the vessels, *in one direction only;* which we judge to be inexplicable by any conceivable alteration of the *propulsion* of the blood by those vital powers which experiments authorize us to ascribe to the vessels of the mother; and regard therefore as an indication of a vital *attraction*, acting similarly to the endosmose of dead fluids, but producing such movement as the simply physical properties of animal fluids will not explain, and therefore strictly a vital power.†

4. The growth of the embryo is slow in the earlier months. The form of the trunk is always considerably curved, but the extremities, when first seen, stand out from the body, and are afterwards folded in. The distinction of textures is very gradually effected, so that bone is not distinctly formed before the end of the second

* See particularly Tiedemann, Traité de Physiologie, § 265, 469; also De Baer, in Breschet's Repertoire, 1828; Prevost and Dumas, in Ann. des Sciences Naturelles, t. 2, 3, 12; Allen Thomson in Edin. Phil. Journal, 1830.

† See Baly's Muller, p. 249.

month,—muscles and fat not until the end of the third; and several organs cannot be perceived sooner than the fourth, at which time the weight of the embryo is hardly above two ounces; after this time it is called the Fœtus. The part of a glandular organ first formed is always the excreting duct, from which the other parts seem to shoot. The distinction of the grey and white matter of the brain is never distinct in the fœtus; but the parts of the nervous System which are first formed, are those that consist ultimately of white matter.* The head of the fœtus, in a great majority of cases, lies ultimately in the lower part of the uterus.

5. After the heart is distinctly formed, and the vessels contain red blood, and when the nourishment must be chiefly drawn from the placenta, the heart, for a time, consists of one auricle and one ventricle only, from which one artery arises, and the septum is afterwards gradually formed, the aorta separated from the pulmonary artery,† and the peculiarities of the fœtal circulation established, about the end of the second month.

6. This circulation takes place in the following manner: From the placenta the blood ascends by the single contorted umbilical vein to the umbilicus, and thence by the edge of the broad ligament to the liver, where it joins the left branch of the Vena Portæ, and is distributed for the most part through the left lobe of the liver,—part, however, passing forward by the ductus venosus, directly to the vena cava ascendens, which the rest likewise enters after being distributed through the liver.

When the blood of the vena cava ascendens reaches the heart, the greater part of it is directed at once to the

* See Tiedemann's Anatomy of the Fœtal Brain, translated by Bennett.

† Allen Thomson, loco cit.

left auricle; the Eustachian valve, in front of it, preventing much admixture with the blood of the right auricle, at least until the later months, when this valve is shortened. From the left auricle it is projected into the left ventricle, and thence into the aorta; and nearly the whole contents of the left ventricle appear to pass into the carotid and subclavian arteries, to supply the upper parts of the body, and upper extremities.* Returning from these by the vena cava descendens, the blood passes through the right side of the heart, and is projected by the right ventricle and pulmonary artery, partly into the lungs, but chiefly through the canalis arteriosus into the commencement of the descending aorta, which it appears completely to fill, at least during great part of the fœtal life. From the internal iliac arteries a great part of this blood ascends by the two umbilical arteries at the sides of the bladder, and passing out by the umbilicus, is carried by the cord to the placenta;—while the rest is circulated through the lower parts of the fœtus, and rejoins it in the vena cava.

The arrangements now described are evidently calculated, not only to expose the blood of the fœtus to the salutary changes which it undergoes at the placenta, but likewise to send most of this blood to the upper parts of the body of the fœtus before it visits the lower parts; to allow a small portion only of this blood to have access to the lungs of the fœtus; and farther, to secure the cooperation of both ventricles of the fœtal heart in the circulation through its body.

7. After this circulation is established, it seems to be a general law, that the growth of organs is proportioned to the development of, and flow of blood through, the

* See a translation of Kilian's work on the Fœtal Circulation, in Archives de Medecine, 1828.

bloodvessels supplying them. The deficiency of parts of the body in monsters may generally be traced more or less directly to this cause; and the development of the Nervous System, in particular, appears strictly proportioned to the development of the vessels supplying it,—the nerves being first formed in most parts of the body, the spinal cord before the brain, and the brain before the cerebellum, and the growth of both these organs taking place in the direction in which the branches of the carotid and vertebral arteries extend themselves.*

8. There are certain parts fully developed in the fœtus, which shrink and become apparently useless in the adult, particularly the Thymus Gland, situated between the layers of the anterior Mediastinum, and the Supra Renal Capsules. The liver and thyroid gland are likewise of larger size in proportion to other parts than in the adult; and the urachus connecting the bladder with the umbilicus, has no known use in the human fœtus. Another curious fact is, the development of parts of organs, which afterwards shrink and become rudimentary, even during the fœtal life; of which the most striking is the caudal prolongation of the vertebral column and spinal cord during the first three months; the membrana pupillaris, which lies across the pupil in the earlier months, and the prolongation of the cœcum, which afterwards becomes the Processus Vermiformis, belong to the same class. And a still more curious process is the descent of the testes, from their position on the Psoæ muscles, through the abdominal rings to the scrotum, and the change connected with that movement, in the adjoining portions of peritoneum.

8. The circulation in the fœtus is very rapid, the pulsations of the heart above 120. The secretions, and

* See particularly Serres, Anat. Comp. de Cerveau.

more particularly the excretions, must necessarily be much restrained during the fœtal life; but a whitish unctuous substance is formed on the surface in the later months; and there is a copious secretion into the intestines (which are longer in proportion to the size of the body than in the adult), both of mucus and of bile, from which the greenish liquid matter called Meconium is formed, which exists in the lower intestines during the later months, and is discharged soon after birth. In some instances this has taken the exact form of hardened fæces; and from this circumstance, and more especially from the contents of the lower intestines shewing little or no albumen, while those of the higher intestines contain albumen in abundance, it appears probable, that there is a process of Digestion of the contents of the intestines during fœtal life, on which the nutrition is partly dependent.* The albumen appears, from Dr Lee's observations, to descend from the liver by the hepatic duct; and thus the main use of the great supply of blood to the fœtal liver appears.

Sir A. Cooper has shewn, that a function very similar to that which has thus been ascribed to the liver, is performed in the fœtus by the thymus gland; *i. e.* that a fluid is formed there quite analogous to chyle, which passes by a lymphatic branch into the jugular vein, along with the thoracic duct; another fact shewing how different a process the assimilation of blood in the body of the fœtus is from simple transfusion.

The general law of the necessity of Excretion certainly applies to fœtal life, at least in its later stages. This appears particularly from the quantity of bilious matter

* See Geoffroy de St Hilaire, Philosophie Anatomique, p. 288; and more particularly Drs Lee and Prout, in Philosophical Transactions, 1829.

(meconium) laid up in the intestines of the fœtus, and discharged after birth; and from the observation of Dr Lee and Dr Prout, confirming previous statements by Mr Howship and M. Billard (and since confirmed by others), shewing, that when the urinary passages have been obstructed in the fœtus, they have been found distended with a fluid which has shewn, on analysis, a small but clearly ascertained quantity of urea.* This substance has indeed been detected in the liquor amnii;† and urinary calculi have been found obstructing the ureters in the fœtus. Part of the use of the circulation of the blood from the umbilical vein through the liver of the fœtus may probably be, to throw off there certain portions of the ingesta corresponding to those which, in the adult state, are thrown off from the recently introduced aliments, both at the liver and in the lungs.

The power of generating animal heat is feeble in the fœtus, its temperature being 92° or 93°,—which is to be expected from its venous blood being less different from its arterial than in the adult,—from its small supply of oxygen, and deficient secretions. In these circumstances, and in the greater size of the particles of its blood in the later months, as proportioned to the size of the heart and vessels, its vitality approaches to that of cold-blooded animals.

The weight of the lungs of the infant is in general nearly doubled after respiration is established, but the proportion of their weight, either before or after that change, to the whole weight, is exceedingly various; being, according to the observation of Chaussier, from $\frac{1}{27}$ to $\frac{1}{130}$ in children still born, and from $\frac{1}{10}$ to $\frac{1}{48}$ in those dying very soon after birth. The whole weight, at birth,

* Medico-Chirurgical Transactions, vol. xix. p. 238.

† Rees in Trans. of British Association at Newcastle, 1838.

is, on an average, about 7 lb., and the length about 20 inches.

The changes on the uterus which attend the development of the ovum within it, likewise demand attention. These are, not only very great enlargement of size, but softening of texture, and alteration of form, which take place gradually, and somewhat variously. For the first three months the uterus remains in the pelvis, and its absolute increase is slow; but in the next three it increases more rapidly, and rises nearly, or quite, to the umbilicus, and, by the end of pregnancy, nearly to the sternum. Its shape is gradually altered, first by the increase of its transverse diameter at its central and lower part, by which it becomes more oval, and afterwards by the expansion of its cervix, which in general takes place almost entirely in the three last months, and furnishes the surest sign of the visible enlargement of the abdomen depending on the development of the uterus.

It is well ascertained by numerous observations, first made by Kergeradec and Dr Kennedy, that the blood passing through the plexus of large vessels at the part of the uterus to which the placenta is attached, produces a peculiar sound at that part, which may be often recognised at the fourth or even third month, and easily distinguished from the sounds of the fœtal heart, which are also in general distinctly perceptible in the latter months.*

The constitutional effects which attend pregnancy are, *first*, suppression of the menses, which is nearly invariable; being in fact the natural result of the formation of the membranes which line the inside of the uterus closely, and cover its mouth, and never separate from it in the healthy state of pregnancy;—*secondly*, the enlarge-

* Dublin Hospital Reports, vol. v.

ment of the mammæ during the last half of the time, and more particularly the formation of the brown areola around the nipple;—*thirdly*, various dyspeptic symptoms, particularly the morning sickness;—and, *fourthly*, various nervous symptoms, particularly mental languor or irritability. But these, although often very obvious, are not exclusively characteristic; and the dyspeptic and nervous symptoms are in some cases slight, and in many abate considerably after the third month. The movements of the child may be felt occasionally, but of very various strength, during the last four or even five months.

The usual duration of pregnancy is just about 280 days. Many children are born before this time, but very few after it; and the law which allows a child to be legitimate if born six kalendar months after the marriage of the mother, or ten months after the death of the reputed father, is generally thought to embrace all possible cases. Yet cases have occurred, in which there was good evidence of children having lived that were born at or even before the sixth month, and of parturition having been delayed beyond the tenth.*

The contraction of the uterus, on which parturition depends, is not the effect of its distention by its contents, but of a change in the vital actions going on in itself; for it is observed, in a certain degree, at the usual time, even in the case of extra-uterine conception. It appears from experiments by Magendie, that there are likewise changes in the placenta, towards the end of pregnancy, tending to the gradual dissolution of part of the vascular union between it and the placenta, whereby the hæmor-

* See, for example, Edinburgh Medical and Surgical Journal, vols. xi. and xxv.; Velpeau, Traité de l'Art du Accouchemens, &c. t. i. p. 377; Belloc, Med. Legale, p. 77; Foderé, Med. Legale, t. ii. p. 142; London Med. and Surg. Journal, 1828.

rhage attending the ultimate separation is no doubt lessened.

The principal changes during parturition are these:

1. The contractions of the uterus cause pains, recurring at intervals, and these gradually diminishing, for some hours, referred to the back, abdomen, pelvis, and thighs; and, along with these, gradual dilatation of the os uteri.

2. When this is accomplished, the membranes are more or less protruded, and then burst, and the liquor amnii escapes.

3. There is after this an increase and change of the painful contractions of the uterus, aided by sympathetic actions of the diaphragm and abdominal muscles, by which the head of the child (in natural labour) is forced down,—the vagina and external parts being stretched and unfolded to make room for it; and the head changing its direction as it descends, so that the occiput, from being directed towards one of the acetabula, comes to be behind the arch of the pubes, and the face in the hollow of the sacrum. After the head has passed the external parts, the pain becomes less urgent, and the rest of the body passes more easily.

5. There is subsequently a slighter renewal of the painful contractions, ending in the discharge of the placenta and membranes; then a bloody discharge for some days, with occasional pains, by which coagula are thrown off; a whitish discharge for some time longer; and the uterus gradually returns to its original form and situation in from twenty to thirty days after delivery.

Dr Granville has stated that the uterus at the time of delivery, attains a temperature ten or twelve degrees higher than has been observed in any other part of the body.*

Phil. Trans. 1825.

The singular circumstance of the sudden closure of so many open mouths of vessels, and rupture of smaller vessels, on the inner surface of the uterus, at the parts covered by the placenta, without dangerous hæmorrhage, depends chiefly on gradual and uninterrupted contraction of the uterus, constringing the mouths of the vessels; and most cases of dangerous hæmorrhage, depend on imperfection or interruption of this tonic contraction.

It may be remarked here, generally, that uterine hæmorrhage, leading to separation of the placenta and abortion or premature labour, may very frequently be referred to one or more of the following causes: General weakness, and especially unusual susceptibility, of those impressions in the nervous system which are apt to influence the circulation; general, and more particularly local, plethora; any sudden excitation of the system, whether from physical or mental causes; febrile disease, especially such as proceeds from a contagious poison; local injury, whether from external or internal causes, in the neighbourhood of the uterus. There are also many cases in which abortion depends on original malformation or fatal disease of the fœtus. There are cases which we cannot refer distinctly to any of these causes; and it has been observed, that such cases are remarkably prevalent in certain times or seasons.

The most important change in the mother, consequent on parturition, is that which takes place in the mammæ, which are already much enlarged, and already, in general, secrete and discharge a small quantity of serous fluid. Within two days after parturition, the fluid assumes the character of milk, which it retains (the proportion of curd however increasing) for many months afterwards. Its discharge is effected, in consequence of the arrangement of the ducts of the gland, by a certain erection of the

nipple, as well as by the suction of the child. The flow of blood to the mammæ, during the whole time of nursing, is very much increased, as is obvious from their increased tendency to inflammation. The *sympathetic* change on the secretion of these glands, according to what was formerly stated, is probably dependent, at first, on sensations which result from the action going on at the uterus. Certainly in this, as in other cases to which the term Sympathy is applied, it is by no means a general law, that every change at the uterus is followed by a change on the mammæ. And after parturition, it is certain that the continuance of the secretion depends very much on the emotions excited in the mother by the sight of the infant; and this not only in the human race, but even, according to the observation of Hunter and of Roulin, in the lower animals.*

The important changes in the fœtus, consequent on parturition, are the effects of the interruption of the flow of blood along the umbilical cord; and of the powers of *Sensation*, which are unnecessary for any of the purposes of fœtal life, being excited by the new circumstances in which it is placed. Its first respiration may be ascribed, partly to the cessation of the small supply of imperfectly arterialized blood, which its lungs had received from the placenta, but chiefly to the novel impression of cold air on the surface of the body. Muller considers it as the effect of the first impulse of truly arterial blood on the medulla oblongata; but that supposition is immediately met by the difficulty that the first jet of truly arterial blood from the heart must be posterior to the first inspiration. The changes in the circulation within the chest, the gradual closure of the foramen ovale, and the more rapid oblitera-

* See Journal of the Royal Institution, No. II., and Annales des Sciences Naturelles, t. xvi. p. 24.

tion of the canalis arteriosus, for which provision had already been made in the altering form of the parts, may be ascribed partly to the expansion of the lungs, and the vital and chemical actions established there, which *solicit* the flow of blood into the lungs, and therefore fill the left side of the heart from them. The changes in the lungs themselves, their great increase of absolute weight, and great diminution of specific gravity, which are likewise effected gradually, are the natural result of the admission of much additional blood into their vessels, and of air into their cells. The continuance of the acts of respiration, the instinctive movements of the limbs, eyes, &c. and the instinctive acts of sucking and deglutition,—being all the natural effects of sensation in the living body, and especially of the establishment of the feeling of anxiety from want of air, and of the appetites of hunger and thirst,—are all to be ascribed to the increased Sensibility which results from the action of perfectly arterialized blood on the nervous system. Thus it is that Life, which, during the fœtal state, is Organic only (and may therefore be maintained without brain or spinal cord), now becomes truly Animal, and is placed in dependence on Sensation.

Another subject of importance in this department of physiology, is the influence of the constitution and habits of parents on their offspring.

That the stature, complexion, forms of features and limbs, &c. as well as the mental peculiarities of the offspring, frequently bear a strong resemblance to those of the parents, is matter of familiar observation;—it is certain also, that resemblances in these respects are observed nearly indiscriminately to both parents;—and it has often been noticed, that such peculiarities have passed over one generation, and appeared in the next. Pecu-

liarities of formation, such as supernumerary fingers or toes, have in like manner often been hereditary in families,—sometimes descending by the females, and sometimes by the males,—and yet been found only in a certain number of the members of these families.* In like manner longevity is very often observed to be hereditary;† and it is therefore quite in conformity with other ascertained facts, that we find the tendency to certain diseases, particularly to Asthma, Gout, Mania, and the various forms of disease which are ranked together under the term Scrofula, disease of the heart, or liver, even to the Diabetes, to be much greater in some families than in others; although in many cases it is only by the action of well-marked exciting causes, that such diseases, even in persons so predisposed to them by hereditary constitution, are produced.

Various observations appear to indicate, that the sex of the offspring is in some measure dependent on the relative energy of the parents; being most frequently male, when the male parent has been of the stronger habit of body, and *vice versa.*‡ Whatever be the causes acting on parents, which influence the sex of their offspring, these causes must operate, on the whole, very uniformly over the world, and so as to cause a slight preponderance of the number of males, the male births exceeding the female very generally in all countries, and nearly in the proportion of 21 to 20.

The age of parents must also, no doubt, influence the

* See Carlyle in Philosophical Transactions, 1814; and Haller, Elem. Physiol. tom. viii. p. 96.

† See a collection of cases of this kind in Sir John Sinclair's Code of Health and Longevity, vol. i. p. 27.

‡ See Girou de Buzareingues in Ann. des Sciences Naturelles, tom. xv.

constitution of their offspring ;—those who are in the vigour of life being best fitted for the procreation of children of strong constitution ; but statistical statements from different countries shew, that the average productiveness of marriages is very different in different stages of advancement and civilization—evidently because marriages are usually contracted much later in some of these countries than in others,—without any corresponding difference in the average health of the community ; from which it may be inferred, with more confidence than from any individual observations, that both men and women are equally capable of the procreation of healthy offspring during a considerable part of their lives.

We have no means of judging in what manner peculiarities, either of the male or female parents, are impressed on their offspring; but it is an important fact, that the influence of the male, in the case of some animals, is not confined to the ovum which he actually impregnates; the peculiarities of a male animal, that has once had intercourse with a female, having been distinctly recognised in the offspring of subsequent connexions of that female with other males.*

The acquired habits, and mode of life of parents, have likewise a very important influence, which is well ascertained on a large scale, but cannot be easily demonstrated by individual instances, on the character of the vital actions which their offspring will exhibit. In so far as the mode of life of parents is permanently debilitating, and disposes them to scrofulous disease, it is certain that it will generally give a similar tendency to their progeny ; as is evident on comparing the amount of scrofulous disease in the young children of a great town, with its amount

* As in the instance of an Arabian mare that had been once covered by a quagga. Philosophical Transactions, 1821.

in the previous generations of the same families, if engaged in agricultural employments. The effect of habits of parents on the vital actions of their offspring is well illustrated by the great variety of appearances assumed by animals when domesticated, and their return, in the course of a few generations, in a state of nature, to a single and uniform type.*

But a more singular fact, which appears well ascertained in regard to certain animals (dogs and horses), and probably in regard to the human species also, is the transmission, to the second and third generation, of habits not natural to the animal, but acquired by education and training.†

Again, it is certain that various incidental circumstances affecting the mother during gestation, may influence the nutrition and subsequent vital actions of her offspring. It appears, from the observations of Geoffroy St Hilaire,‡ that preternatural adhesions of parts of the fœtus to the membranes and the placenta occur occasionally, and so confine and derange the circulation in, and development of, the fœtus, as to produce various kinds of monstrosities; and both from his observations and those of many others, it seems well ascertained, that such derangements of the vital actions within the uterus, as well as inflammations and other diseases of the fœtus often fatal to it, may be produced either by injuries, or by sudden and violent mental emotions of the mother, when

* See Isidore St Hilaire, "Considerations sur les Mammiferes;" and "Recherches sur quelques Changemens observés dans les Animaux Domestiques," &c. by Roulin, in Ann. des Sciences Naturelles, t. xvi.

† See Roulin's paper, above quoted; and the report on it by Geoffroy St Hilaire.

‡ Philosophie Anatomique, p. 208 and 527.

these are not so powerful as to cause immediate abortion. If the observations of Sir E. Home* shall be confirmed, that nerves may be distinguished in the placenta and umbilical cord, the efficacy of mental emotions, on the growth of the fœtus, may be more easily understood. It is much more doubtful, whether the precise nature of the alteration effected in any case on the growth of the fœtus, can be determined, as is vulgarly supposed, by the images in the mind of the mother; but as we know, from such facts as that noticed in last page, that the peculiarities of a male animal may influence the products of conceptions in which he is not himself concerned, and can hardly conceive any other mode than by the intervention of sensation and other mental acts, by which that influence can be transmitted, we are not entitled to deny the possibility of such an agency of mental affections.†

* Philosophical Transactions, 1825.

† See Allen Thomson in Art. Generation, above quoted; also Dr Montgomery's Exposition of the Signs and Symptoms of Pregnancy, &c.

CHAPTER XIX.

OF PECULIARITIES OF AGE, SEX, AND TEMPERAMENT.

THE vital actions of all warm-blooded animals, immediately after birth, approach in several respects to those of cold-blooded animals. Their circulation, although very rapid, is easily repressed, particularly by cold ;* their power of generating heat is feeble, and in the human species and many others, would be insufficient, of itself, to preserve life ; their sensibility, and mental powers, are imperfectly established ; and their lives are chiefly spent in sleep ;—but, on the other hand, they have more endurance of life, in different circumstances ; the same degree of reduction of their own temperature,† the same length of suspension of the function of respiration,‡ and the same amount of destruction to the Nervous System,§—is not fatal to the vitality of their organs of circulation, as in adult animals.

The following appear to be the most important peculiarities which appertain to the periods of childhood and early youth, gradually diminishing as life advances :

1. The capillary vessels, and particularly the capillary arteries, are much more numerous in all the textures, and bear a much greater proportion to the larger vessels, as is obvious on comparing the red lines in an aged counte-

* See Edwards, De l'Influence des Agens Physiques, &c. Part iii. ch. i.

† Ibid. Part iv. ch. ii.

‡ Ibid. Part iii. ch. iv. and Part iv. ch. vi.

§ Legallois.

nance, with the diffused bloom of youth, and as is more distinctly shewn, by injections of subjects at different ages; so that the blood must diverge much more into the interior of the textures, than in adults.

2. During the whole period of youth, the irritability of the organs of circulation is evidently greater than in adults; the number of pulsations of the heart, at first double that in the adult, is only gradually reduced, and is easily raised by various kinds of excitement; hence a febrile state, with increased heat of skin, is much more easily produced than in advanced life, and if excited by inflammation, is of greater intensity and duration, than that which the same extent of inflammation, in advanced life, would occasion.

3. The vital action of the vascular system, although more easily excited and increased, has not (according to the general observation of physicians) so much strength or endurance, as in adults. It is more easily depressed, not only by cold, as already stated, but by evacuations, particularly of blood.

4. The organic functions going on in the capillary vessels, both deposition and absorption, take place with greater rapidity; as appears, not only from the growth of the body, but from digestion being more rapid, and more frequent reception of food being required; from the bowels being more open; and again, from the body wasting more rapidly under the influence of any disease which impairs digestion.

5. The peculiarities of the functions of the Nervous System during youth are analogous to those of the organs of circulation. The Nervous System appears more susceptible of change of all sorts, or to possess more *mobility*, than in more advanced life. All objects of sensation impress themselves more strongly on the attention, and

thereby on the recollection, and knowledge of all sorts is more easily acquired. All the natural desires are more lively, and the flow of thought more rapid; but the power of continued voluntary attention, either to objects of sense, or to mental abstractions, is less. Muscular motion is more grateful; continued inactivity is felt as a greater restraint; and variations of any combined voluntary movements are more easily performed, so that the physical education is easier; but the strength and endurance of the power of voluntary muscular contraction are inferior to what they afterwards become. Mental emotions are more easily excited, and their influence on the body is more obvious; but they are also more transient and capricious.

The body does not attain its full height till some years after the time of puberty; the growth in other directions continues, although slowly, for a time after the full height is attained; and it is not until the growth in all directions is completed, that the bodily strength is greatest.

The brain is probably the first part of the body which attains its full size, being, in general, as large about seven years of age, as subsequently. The growth at the extremities of the body appears manifestly to be accelerated by a sedentary life (when the health continues good), and to be somewhat retarded by habits of muscular exertion, which solicit the flow of blood into muscular parts. The growth is perhaps accelerated, and certainly invigorated, by frequent alternations of temperature within certain limits; but is permanently checked by habitual exposure to extreme cold, as in the Arctic Regions.

Growth, in all parts of the body, after birth, appears to take place, not as in the earlier periods of fœtal life, by deposition from the fluids to form new organs, but by the extension of parts previously organized. And the vessels

of every organized texture possess the power (although in very various degrees), of throwing out, under certain circumstances of injury or disease, lymph which shall gradually assume the properties of that texture. But the deposition of bone, whether between membranes, as in the cranium, or in cartilages, as in the extremities, takes place in parts already formed; it is always preceded by increased vascularity; it is well ascertained, that the vessels of periosteum, as well as of bone, deposit the osseous matter; and the deposition of the new bone, in ordinary growth, appears to be chiefly at the extremities of the bony fibres already formed. The cartilaginous rings which unite the epiphyses with the shafts of the long bones, and the sutures of the bones of the head, allow of growth of bones taking place in this way, without any extension of fibres already formed; and some experiments of Mr Hunter* have been thought to indicate that bones never grow in this last way. But the changes which take place in the lower jaw long after birth, are enough to shew, that bony fibres may grow by extension of their parts, as well as by deposition at their extremities.

Most of the second set of teeth are formed within, as well as protruded from, the maxillary bones, at different periods after birth.

The changes which take place on the body in old age (but which begin at very different periods of life in different persons), cause peculiarities nearly the reverse of what were remarked in youth. The circulation in the capillary arteries becomes gradually more confined to the larger of those that communicate with veins, while many of the smaller are obliterated; and the power of genera-

* See Transactions of a Society for the Improvement of Medical and Surgical Knowledge, vol. ii.

ting heat is again diminished. The circulation is somewhat retarded, and gradually enfeebled, notwithstanding that the pulse often feels strong, by reason of the diminished elasticity and vital power of the arteries. The same amount of inflammation, or of other diseased states of the body, excites less febrile reaction than formerly; and any diseased action established in the vascular system shews less tendency to spontaneous abatement. The cells of the lungs are remarkably enlarged, so that the action of the blood and the air in the lungs must be diminished. Nutrition of all the textures takes place more slowly, and the *decrementum corporis* is established; the textures become generally more rigid, the proportion of fluids being diminished; the cornea is flattened; many of the cartilages, and sometimes certain of the membranes (independently of any decided disease), become bony; the senses become somewhat blunted; muscular exertion, especially any new combination of muscular actions, becomes irksome; as the vital powers of the muscles diminishes, the desires become less keen; the disposition to fix the mind on any new object of thought is lessened; and the associations connected with these becomes few and feeble; so that the recollection of them is soon lost. Mental emotions are less easily excited, and their influence on the body is less obvious. But in different individual cases, there is very great variety in these respects.

The peculiarities of the female constitution, in the functions common to both sexes, are seen chiefly between the time of puberty and the cessation of the menses. According to the observation of Le Canu, the blood in women contains more water, and less of the solid matter of the crassamentum than in men; the proportions on an average of 10 cases being as follows, in 1000 parts:

	In Men.	In Women.
Water,	789.3	504.3
Solids of Crassamentum,	132.5	115.9
Solids of Serum,	78.2	79.8

The branches of the descending aorta, supplying the abdomen and pelvis, are not only larger in women, but are more habitually liable to variation in the quantity of their contents; and hence probably it happens that inflammations, and other diseases of the parts supplied by these vessels, are more easily induced. The nourishment of the organs concerned in locomotion is less active, and that of the cellular and adipose textures generally more active, than in man. But the chief difference is in the functions of the nervous system. The sensations in women are probably more acute, or their minute differences more easily discerned; the mind is more easily impressed by any new object of thought; the disposition to active and sustained exertion, whether mental or bodily, is less, and the mental emotions are stronger, and arrest the attention more forcibly, than in men; so that women are more habitually under their influence. They are less guided in their conduct, by simply intellectual acts, directed to the attainment of definite objects, and are more apt to be biassed in their judgments by preconceived feelings; but these feelings are very generally disinterested, and true to the purposes for which they are destined by nature. The great influence, on all the functions of women, of sensations and emotions, and of changes in the nervous system, which affect the other organs nearly in like manner as these mental feelings do, is very important in reference to many of their diseases.

The influence of habits and external circumstances on the human constitution is obviously great, but not easily referable to distinct principles. It is illustrated by the difference between the vigorous circulation, muscular

strength, strong mental determination, but deficient sensibility, or versatility of mind, which often characterize men habituated to the labours of the country,—and the feebler circulation, inferior muscular power, and less tenacity of purpose, but greater acuteness of sensibility, and greater activity of mind, generally observed in the inhabitants of great towns; and such differences modify very materially both the kinds of disease to which these persons are liable, and the action of remedies upon them. A difference in some respects similar is seen on comparing the usual temperaments of the inhabitants of the North and South of Europe.

On the curious subject of the different races of mankind, ample information may be found in the works of Lawrence, Prichard, Mayo, Desmoulins, Edwards, &c.

The interest which has been attached to observations on this subject, depends very much on their tendency to elucidate the question, whether all the varieties of the human species can be reasonably supposed to have sprung from the same origin. Cuvier, although ranking them all as of one species (because the sexual intercourse between individuals of all varieties is prolific), evidently inclined to the opinion that at least three distinct races have been created, the Caucasian, or Mesobregmate—the Ethiopian, or Stenobregmate—and the Mongolian, or Platybregmate variety.

Of the first of these, the oval-shaped head, the high features and soft smooth hair and long beard, are more distinctive marks than the colour of the skin, which is generally but not universally fair.

The second is distinguished by the narrow or compressed head, the projecting jaws, depressed nose, and woolly hair, with which the black colour of the skin is very generally combined.

The third is characterized by the breadth of the skull, and breadth between the eyes, the projection outwards of the cheek bones, and obliquity of the orbits; the hair is lank, the beard short, and the skin usually olive-coloured or tawny.

The most characteristic examples of these races, in the European, the Negro, and the Calmuck or Chinese, are strikingly contrasted; and it is certain that arts, sciences, and civilization, have made the greatest progress in the first, have hardly advanced at all in the second, and only imperfectly in the third race. But when we compare all the actual varieties of the species with these standards, we find great difficulty in fixing the proper place of many, and may be led ultimately to think it as probable that they are all derived from one as from these original stocks.

Dr Prichard* has been lately at great pains to establish, that the variety of languages bears no relation to the supposed descent of the different tribes of men from these three roots; the greatest diversity, not only as to the derivation of individual words, but as to the whole structure of language, being found in nations belonging to the same family, *e. g.* in the Calmucks and Chinese; and again, the same language, or languages nearly akin to one another, being spoken by nations evidently belonging, according to their physical characters, to different families; as in the case of the Turks of the Caucasian race, and some of the tribes of Tartars, of the Mongolian.

Perhaps, however, too much reliance has been placed on this argument. We know that a great diversity of languages may arise in the same race of men, if thinly

* See Reports of British Association, 1832, p. 529.

scattered over an extensive country, as in America; and we can easily understand how the same language may gradually become common to very different races, if one should be predominant in number or power. The analogies of languages are probably more important as marking the connexions of nations in the more advanced periods of their history, than as assisting us to trace their origin.

But independently of this consideration, there are two others which are strongly adverse to the theory of the triple origin of the human race:

First, The number of races which have been observed and distinctly described is so great, that if we adopt that theory, we shall be obliged to admit that from each original stock a number of distinct races have sprung, some of them differing from one another nearly as much as the original models; at least differing so much as to make it quite possible, that whatever causes produced those diversities, might explain all the differences observed at the present day; and some of these races seem evidently intermediate links in series, by which all races may be connected. Thus the Hottentots have been described as partaking of the character of the Ethiopian and Mongolian race, and the Copts as partaking of those of the Ethiopian and Caucasian; and the Caffres of Southern, and the Tibboos of Northern Africa, differ from the general form of the Negro nearly as much as from the colour of the European. Among the Asiatic tribes there are similar varieties; the Hindoos, although referred to the Caucasian race, differ materially from any Europeans; and even among the Europeans, decidedly of the Caucasian family, there are peculiarities long hereditary and widely extended, *e. g.* that of the dark-haired melancholic Spaniard and

the fair-haired and blue-eyed Swede or Prussian (whether sanguine or phlegmatic), which it may seem nearly as difficult to reduce to a common character, as those which distinguish the Calmucks and the Tartars.

Secondly, We know that in all animals in a state of domestication, more nearly approaching to the condition of the human species than any other in which animals are placed, distinctions of *breeds* are gradually formed, as obvious and complete as those which characterize the races of men, and transmitted through many generations nearly unimpaired, yet certainly not originating in specific differences.

In what manner the distinctions of breeds of animals and races of men are produced, and then transmitted, we are by no means accurately informed; but in both cases it may be confidently asserted, 1. That the varieties are so numerous and well marked, that if we suppose each to have *retained* its characters unchanged throughout all generations, we must suppose not a few, but *many*, distinct creations; and, 2. That if we admit that each has *changed* its character gradually in the course of ages, so as to allow of the descent of the whole from a *few* original models, these gradual changes must have gone to so great an extent, as to authorize our believing that a single pair may have given origin to the whole.

In Europe, it would appear that two races, in some respects considerably different, have existed almost from the earliest periods of history,—the one characterized by black hair and eyes, and a dark complexion; and the other by light coloured or red hair, generally blue eyes, and a fair or florid complexion. Individuals of the first race belong generally to the nations originally Celtic; they constitute the bulk of the population of France,

Italy, and Spain, and have been divided by medical authors into those of the Choleric and those of the Melancholic temperaments. Those of the second race are generally of Gothic origin ; they predominate greatly in Germany, Denmark, and Sweden, and have been divided into those of the Sanguine and those of the Phlegmatic temperaments.* In the British Islands, and in Switzerland, there appears to be a greater mixture of these races than in most other countries.

The differences between the great divisions of black and white men, and some of the subordinate divisions of nations, in different quarters of the globe, are much more striking. The secretion on the cutis vera, which gives the black colour to the skin, appears to assist in fitting men for residence in hot climates ; because, although such skin, by absorbing more caloric, rises to a higher temperature under the sun's rays than white skin does, yet it does not inflame so readily from a rise of temperature ;† and as the radiation of caloric from it, when its temperature is higher than that of surrounding objects, is greater than that from white skin, those who have it must enjoy greater alternations of heat and cold.

But it appears evidently from what has been observed of the comparative liability of whites and blacks to different diseases, (especially to remittent fever, inflammations of different parts, and the Indian cholera), and of the difference of the course of these diseases in them, that the various races of blacks and whites differ from one another in circumstances not to be explained by the colour or texture of their skin, and which have not yet been satisfactorily investigated.

* See Gregory's Conspectus, cap. xxiii.

† Sir E. Home, in Phil. Trans. 1821.

The study of such varieties, consistent with health, in the human species, forms the proper connecting link between the subjects of Physiology and Pathology. These subjects have been often treated together; but it is impossible to give a satisfactory account of the changes that take place in any disease, or even in consequence of an injury, without reference to the Physiology of different parts of the system; and therefore all such discussions are better postponed, until the healthy condition of all the functions has been examined.

THE END.

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CORRIGENDA.

Page 19, 4th line from foot, *dele* also

Page 64, Note, *for* Fourdan, *read* Jourdan,

Page 112, 8th line from top, *for* " its more attractive powers," *read* " to be the attractive power,"

Page 200, 3d line from foot, *after* " Respiration." *add* " The simplest and most decisive proof of the necessity of this condition is furnished by the experiment of Sir Astley Cooper, in which the carotid and vertebral arteries of a small animal being simultaneously compressed, all the indications of Sensation and of Animal Life rapidly disappear without struggle or convulsion."

1.

ILLUSTRATIONS OF THE BOTANY AND OTHER BRANCHES

OF THE

NATURAL HISTORY OF THE HIMALAYAN MOUNTAINS,

AND OF THE

FLORA OF CASHMERE.

By J. FORBES ROYLE, M. D., V. P. R. S., F. L. S., & G. S., M. R. A. S., &c.

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This Work being now concluded, it is desirable to give a fuller idea of its contents than can be obtained from its title. The Himalayan Mountains, forming the stupendous barrier between the dominions of the British and of the Chinese, and having their south-western bases resting on the heated plains of India, abound in all the forms of Animal and Vegetable Life, characteristic of Tropical Countries in general, and of India in particular. Their gradually-elevated slope, supporting vegetation at the greatest known heights, affords, at intermediate elevations, all the varieties of temperature adapted to forms, considered peculiar to very different latitudes. A gradual approach is thus observed to take place to the Animal and Vegetable forms common in Europe, China, Japan, Siberia, and North America.

Dr. ROYLE, while Superintendant of the Honourable East India Company's Botanic Garden at Saharunpore, within 30 miles of the Himalayas, had great advantages in becoming acquainted with the Natural History and Products of these Mountains. He made Meteorological Observations, collected Geological Specimens, and skins of the Mammalia and Birds, together with Insects, and about 4,000 species of Plants in the Plains of India, and in the Himalayas, as far as Cashmere. Drawings were made of the most interesting of these by the East India Company's Establishment of Painters.

To shew the connection between the different branches of Natural History, and their dependance on the Physical Features, Soil, and Climate of the Country, the work has been divided into two Parts. The Introductory portion treats, first,—of the PHYSICAL GEOGRAPHY of the Plains and Mountains of

India, dwelling especially on the results of the Surveys of the Himalayas, (of which a view from the vicinity of Almorah is given in the Frontispiece,) and the Travels of Messrs. Turner, Moorcroft, and the Gerards, with notices of the elevations of the highest Peaks and Passes. This is followed by a view of the GEOLOGICAL FEATURES of the Plains and Mountains, illustrated by a Plate of Sections, (in which the Author was assisted by Mr. DE LA BECHE,) and three plates of Fossil Plants and Animals, containing 54 figures. The METEOROLOGY is next treated of, and the climate of the Tropics compared with that of the Plains and Mountains of India, with tabular Views of the monthly and diurnal range of the Barometer and Thermometer in the Plains of India. The characteristics of Himalayan Climate, consisting of mildness, and equability of Temperature and of Pressure, at such elevations as Simla and Mussooree, resorted to by Europeans for the recovery of health, are then given.

The Physical Features, Soil, and Climate having been noticed, a general view of the GEOGRAPHICAL DISTRIBUTION of the Plants and Animals which these are calculated to support, is treated of in an Introductory Chapter, in connection with the CULTIVATION at different seasons and at several elevations.

The BOTANY itself is arranged according to the Natural System, under the heads of 207 families, illustrated by colored plates of 197 PLANTS. The observations on each Family consist of a notice of its Geographical Distribution in different parts of the world, an enumeration of the Genera and remarkable species found either in the Plains and Hot Vallies, or in the Mountains of India; and the Vegetation natural to different parts of India is compared with that of other countries enjoying similar climates. This plan was adopted, as giving the most interesting and important general results, and as leading to a just appreciation of the influence of Physical Agents on Vegetation, and as elucidating those principles which require to be attended to in the Culture both of new Plants, and of old Plants in new situations. It also afforded great facilities in treating of the properties of Plants as connected with structure, and for showing the immense resources of British India, and the probable means of still further increasing them.

The subjects of AGRICULTURAL and COMMERCIAL importance which are more fully treated of, are Tea, Cotton, and Tobacco; and the probability of the first being successfully grown in the Mountains, and the two latter in the Plains, is shown by application to Practice of the principles of Science. Also Hemp, Flax, and the Cordage Plants; and, among Medicines, the Cinchonas, Ipecacuanha, Sarsaparilla, Senna, Rhubarb, and Henbane, with many others. As articles of Culture and Commerce, various Timber trees, Gums, Resins, Caoutchouc, Astringents, Dyes, Vegetable Oils, Fruit Trees, the Olive and Carob Trees, Corn and Pasture Grasses, Salep, Arrow-Root, and other articles of diet, are pointed out. As subjects of CLASSICAL Interest elucidated, may be noticed Lycium, Agallochum, or Eagle Wood, Calamus Aromaticus, and Spikenard of the Ancients; also their Costus, which is the Puchuk of Commerce.

In connection with the Climate and Vegetation, it is interesting to notice the Animal Forms, and this has been done in two able papers, one on the ENTOMOLOGY of India, and the Himalayas, by the Reverend F. W. HOPE, President of the Entomological Society, which is illustrated with two colored plates of 20 insects, and the other on the MAMMALOGY of the Himalayas, by W. OGILBY, Esq., Secretary of the Zoological Society; this is illustrated by a figure of Lagomys, (new species,) and also by two of Deer. A list of the BIRDS in the Author's Collection is also appended, and two plates, one of Birds of Tropical Forms found in the Himalayas in the rainy season, and the other of Himalayan Birds of European forms are given.

As the work contains so much of detail as well as of General Views it would have been comparatively useless without easy means of reference. This has been supplied by an Analytical Table of Contents, and by Alphabetical Indexes at the end of the book, extending to 34 pages; also an Alphabetical List of Plates for the Second Volume.

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